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Environmental Effects of Coal Tar-Based Pavement Rejuvenators

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ABSTRACT

Coal tar-based pavement products, including sealcoats and rejuvenators, have been under scrutiny due to the presence of high concentrations of polycyclic aromatic hydrocarbons (PAHs) in the coal tar base. Researchers have found that PAHs mobilize from coal tar sealcoats, primarily through the formation of PAH-laden dust particles. Coal tar-based sealcoats have been banned in many locations in the U.S. due to the concerns over carcinogenic and mutagenic effects of the PAHs they contain. In this research, the environmental impacts of a coal tar-based pavement rejuvenator were investigated. The purpose of this project was to quantify PAHs mobilized from a coal tar-based rejuvenator by evaluating surface coating samples, street dust samples, and catch basin sediment samples for total PAHs. Samples were collected from a neighborhood in New England where the coal tar-based product was applied in 2016. Total PAH concentrations were quantified in the samples using a solvent extraction method and gas chromatography. The concentration of PAHs mobilized from the application site to the surrounding environment provided a snapshot of the possible environmental and health risks of coal tar-based products used for pavement maintenance. Additional research avenues and remediation best management practices were explored.

EXECUTIVE SUMMARY

The use of coal tar-based pavement maintenance products, including sealcoats and rejuvenators, has been of great concern to scientists, engineers, and the public, due to the presence of high concentrations of polycyclic aromatic hydrocarbons (PAHs) in the coal tar base. Researchers have found that PAHs mobilize from coal tar sealcoats, primarily through the formation of PAH-laden dust particles. Coal tar-based sealcoats have been banned in many locations in the U.S. due to the concerns over the carcinogenic and mutagenic effects of the PAHs they contain. In this research, the environmental impacts of a coal tar-based pavement rejuvenator was investigated. While pavement sealants remain on the surface and are directly exposed to the elements, manufacturers claim that rejuvenators will penetrate into the pavement and replace lost bitumens. The intent is that the penetration of the rejuvenators into the material will reduce the binder material viscosity and thereby restore pavement flexibility.

Many PAHs have been found to be probable human carcinogens and toxic to aquatic organisms, raising concern if they mobilize to the environment from the application location. The goal of this project was to assess the mobilization of PAHs from an applied coal tar-based pavement rejuvenator to the surrounding environment. This was accomplished via the following objectives:

1. Quantify the total PAH concentration in the surface coating on pavement subsequent to the application of a coal tar-based rejuvenator,
2. Investigate PAH mobilization from a coal-tar based rejuvenator application site into catch basin sediments,
3. Recommend future investigative avenues to elucidate the environmental impacts of coal tar-based rejuvenators.

Samples were collected from a location where the rejuvenator was recently applied and analyzed for total PAH compounds. Four types of samples were collected and analyzed:

pavement surface dust samples, road surface coating samples, sediment samples from adjacent areas, and catch basin sediment samples. Samples were collected throughout a five-month period and stored at 4 C in clean glass jars until analysis with gas chromatography.

Results indicated that a greater mass of PAHs were mobilized from the application site when compared to a reference site. Total PAH data from three catch basins (two from the application site and one from the reference site) validated the hypothesis that PAHs were leaving the site of application. The possible bioavailability of these PAHs in the surroundings poses potential environmental and health risks.

Further investigation into the fate and transport of the PAH-laden particulate matter that are shed from coal tar-applied surfaces should be conducted. Additional research should collect additional information on the potential aquatic toxicity and human health impacts from this mobilized material. A bioretention feature was designed to limit the mobilization of PAHs from the existing storm water management system into the environment.

STATEMENT ABOUT PROFESSIONAL LICENSURE

Professional licensure protects the public through the assurance that designs are approved by a qualified Professional Engineer. The process of obtaining licensure is demanding and precise to ensure the competency of the engineer in question. Though not all engineers become licensed, those that do obtain a professional engineering license receive certain benefits and opportunities.

The process of professional licensure for engineers can be broken down into four requirements. First, the engineer must receive a bachelor's degree in engineering from an Accreditation Board for Engineering and Technologies (ABET) certified program. Upon graduation, the engineer must pass the Fundamentals of Engineering Exam to earn an Engineer in Training license (E.I.T.). The E.I.T. must then work under a Professional Engineer for four years (typically, as time varies by state) before they can register for the Practice of Engineering Exam. This exam, when passed, allows the engineer to apply for a Professional Engineering License.

A Professional Engineer (PE) is accepted as a competent and reliable figure due to the stringent nature of this licensure process. A PE has the authority to approve designs, be a principal of a firm, consult, and bid for government contracts. A PE also has the responsibility to make sure all designs meet code, safety, and ethical requirements. Thus, all designs described within this report must first be approved by a Professional Engineer before any construction may occur.

CAPSTONE DESIGN STATEMENT

In this project, the design requirement was satisfied through two major efforts:

1. An experimental protocol was designed to obtain representative and meaningful data, and

2. A bioretention feature was designed that could capture the PAH-laden material downstream of the conventional catch basins, thereby reducing the potential for mobilization of PAHs into the environment.

WPI's Major Qualifying Project attempts to go above and beyond the requirements of capstone design experience per the Accreditation Board for Engineering and Technology (ABET); per ABET General Criterion 4,

> *"students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following consideration: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political."*

<u>Economic</u>

Remediation best management practices were explored based on their effectiveness as well as their total cost.

Environmental, Sustainability, Health, and Safety

Design of an experimental method for the detection of PAH-laden dust particles in catch basin sediment illuminated the need for awareness and remediation of these carcinogenic and mutagenic PAH-laden particles mobilizing from coal tar-based rejuvenators. The goal of recommendations moving forward is to establish a better understanding of these coal tar products and their effects on their environment and to determine a more sustainable product/solution that can accomplish rejuvenation in asphalt pavements.

Social and Political

The results of this study highlight the effect that one decision in a local government setting can have on the environmental health of a community. It is imperative that we strive for lifelong learning and awareness to help combat the detrimental effects of purely economic decision making.

ACKNOWLEDGEMENTS

We would like to thank Professor John Bergendahl for his guidance and passion throughout the entire process of this project. We would also like to thank Don Pellegrino and Dr. Jose Rivera Alverez Corena for their assistance with lab procedures and equipment. Lastly, we would like to thank Dr. Peter Van Metre and Dr. Barbara Mahler for their guidance and support in experimental procedures and research.

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CHAPTER 1: INTRODUCTION

Pavement maintenance products intended to extend the life of expensive pavements have been in use for many years, however, recent research has revealed possible environmental and health effects from the use of some of these products. Coal tar-based products, in particular, raise concern due to the presence of carcinogenic chemicals in the material base. Coal tar sealants have been studied by many researchers, including those from the US Geological Survey, the University of New Hampshire, and the University of Oregon, among others. The findings by these researchers on the environmental and health impacts of coal tar-based sealants have been published in peer-reviewed scientific journals. While pavement sealants are designed to remain on the surface and are directly exposed to the elements, manufacturers claim that rejuvenators will penetrate into the pavement and replace lost bitumens. The intent is that the penetration of the rejuvenators into the material will reduce the binder material viscosity and thereby restore pavement flexibility.

These coal tar-based pavement maintenance products can contain a significant amount of coal tar: coal tar-based sealants typically contain 20-35% coal tar products (Mahler et al., 2012), and rejuvenators may contain up to 70-95% coal tar products by weight (McGovern, 1966). Coal tar in itself is a health concern: the National Cancer Institute asserts that, “occupational exposure to coal tar or coal-tar pitch is associated with an increased risk of skin cancer. Other types of cancer, including lung, bladder, kidney, and digestive tract cancer, have also been linked to occupational exposure to coal tar and coal tar pitch” (“Coal Tar and Coal Tar Pitch,” 2017). Coal tar contains many chemical constituents, including polycyclic aromatic hydrocarbons (PAHs). Many PAHs have been found to be probable human carcinogens and toxic to aquatic organisms, raising concern if the PAHs mobilize to the environmental from the location of rejuvenator application.

While the environmental implications of pavement sealants have been researched, there is no published information on the impacts of coal tar-based rejuvenators. The overall goal of this project was to investigate the environmental effects of a coal tar-based rejuvenator recently applied to an asphalt pavement in a neighborhood in Pomfret, CT. Samples were collected from the location where the rejuvenator was recently applied, and analyzed for total PAH compounds. Recommendations for future work and a design for a PAH mitigation feature in storm water runoff was provided.

CHAPTER 2: BACKGROUND

2.1 Coal Tar

Coal tar, coal tar pitch (refined coal tar), and coal tar creosote (oil derived from coal tar refinement) are by-products derived from the carbonization of coal (see Figure 1) ("Coal Tar and Coal Tar Pitch," 2017). While they can be naturally occurring, it is rare to find coal tar products formed in nature. Usually characterized by thick, dark brown or black liquid or semisolid physical features, coal tar gives off a strong smoky and aromatic odor and strong naphtha smell. Coal tar creosote has been widely produced and used in the United States as a wood preservative and was commonly applied to protect utility poles. Products can be extracted from coal tar to be used as pesticides (insecticides, fungicides), in medicines, for animal and bird repellents, and have been used in road paving products, roofing products, and in rubber components.

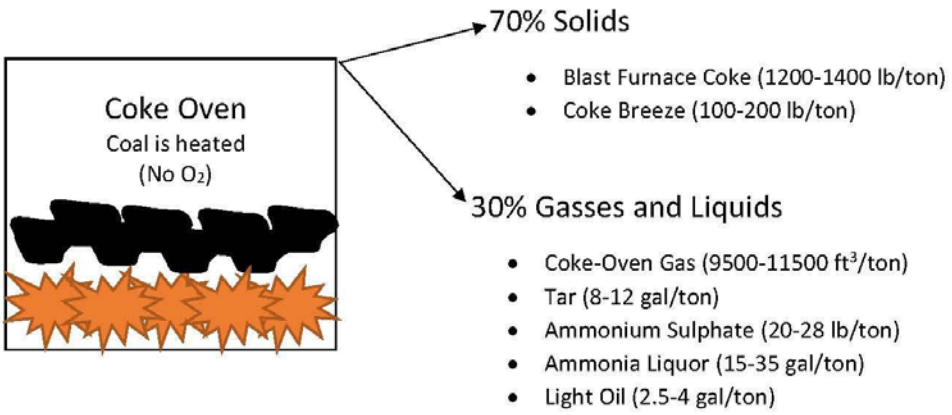


Figure 1: Production of Coal Tar.

As shown by the process in Figure 1, coal tar is a byproduct of the destructive distillation of coal. The process entails the heating of coal in the absence of air; the byproducts of this process can all be considered coal tar products (ATSDR, 2002). This process was in widespread use for producing manufactured gas for lighting and heating in the 19th and early 20th centuries throughout the US and in other parts of the world. At many former manufactured gas plant locations, the coal tar byproduct contamination remains a serious pollution concern that is persistent and recalcitrant.

2.1.1 Toxicological profile of coal tar

Coal tar, coal tar creosote, and coal tar pitch consist of a high percentage of polycyclic aromatic hydrocarbons (PAHs), phenol, and cresols. Many of these chemicals are considered to cause harmful health effects according to the Agency for Toxic Substances and Disease Registry (ATSDR). While most components of coal tar have low aqueous solubilities, there are components of coal tar which are water soluble and can potentially enter groundwater supplies where they can persist for years due to their recalcitrance. While less studied than PAHs, azaarenes, a subclass of heterocyclic aromatic compounds in coal tar in which a nitrogen atom replaces a carbon atom in one of the aromatic rings of a PAH, have a large range of ecotoxicological effects, including acute toxicity, developmental and reproductive toxicity,

cytotoxicity, photo-induced toxicity, mutagenicity, and carcinogenicity (Mahler et al., 2014). According to the US Department of Health and Human Services, even small amounts of coal tar can be toxic to some animals and even potentially toxic to humans (ATSDR, 2002).

Exposure to wildlife has been documented near use of coal tar products; especially near creosote-treated wood. Plants can uptake a very small amount (< 0.5%), but animals such as voles, crickets, snails, bugs, and worms can be easily exposed through their skin, lungs, and/or stomachs to the coal tar products in their natural habitat. It has also been documented that mussels attached to creosote-coated pilings had absorbed the chemicals into their tissue (ATSDR, 2002).

Humans can be exposed to small levels of coal tar daily, but people who work with coal tar in their jobs and people who use coal tar as a medical treatment for eczema or psoriasis are much more likely to receive greater exposure. Coal tar most commonly enters the human body through the skin, but can be ingested accidentally and its vapors can easily enter the bloodstream through the lungs. Coal tar may cross the placenta and because coal tar products can potentially be stored in body fat, they are also found in breast milk (ATSDR, 2002).

According to the ATSDR, eating food or drinking water contaminated with a high level of these compounds could cause a burning feeling in the mouth and throat accompanied by stomach pain. Workers with a daily exposure to coal tar have indicated that even brief exposure to large amounts can result in a rash or severe irritation of the skin, chemical burns of the surfaces of the eye, convulsions and mental confusion, kidney or liver problems, unconsciousness, or even death. Longer exposure to lower levels have also been documented to result in increased sensitivity to sunlight, damage to the cornea, skin damage such as reddening, blistering, or peeling, and potential irritation of the respiratory tract. Skin cancer and cancer of the scrotum have also resulted from long exposure to low levels of these chemical mixtures. The Agency for Toxic Substances offers the caveat that these levels of exposure are much higher than levels that humans are likely to be exposed to through groundwater, food, air, or soil (ATSDR, 2002).

Based on tests with laboratory animals, The International Agency for Research on Cancer (IARC) has classified coal tar as carcinogenic to humans, whereas the EPA determined that coal tar creosote is a probable human carcinogen (Williams et al., 2013).

Chemical constituents in coal tar

Coal tar has many chemical constituents, including polycyclic aromatic hydrocarbons, which have been found to be carcinogenic, mutagenic, and teratogenic. Some PAHs in coal tar are listed in Table 1, along with their carcinogenicity potential. Products containing PAHs were applied to the skin of mice to test "carcinogenic power" by Sir Earnest Kennaway, who found, "110 cancers in 496 mice" over 2 years when exposed to chrysene and dibenzanthracene among other compounds (Kennaway, 1955).

Table 1: Carcinogenic potential of PAHs in coal tar (ATSDR 2009).

PAH	Known Animal Carcinogen	Possible Human Carcinogen	Probable Human Carcinogen
Benz(a)anthracene	✓		✓
Benzo(b)fluoranthene	✓		✓
Benzo(a)fluoranthene		✓	
Benzo(a)pyrene	✓		✓
Dibenz(a,h)anthracene	✓		✓
Indeno(1,2,3-c,d)pyrene	✓	✓	✓
Benzo(k)fluoranthene		✓	✓
Chrysene			✓

2.1.2 Uses of coal tar and coal tar products

Through extraction and processing, some of the many chemicals in coal tar can be utilized in useful products. Coal tar is a “mixture of different carbon compounds that can be used to make soap, fats, dyes plastics perfumes, drugs, pesticides, [and] explosives” (“Destructive Distillation of Coal,” 2017) as well as waterproofing materials and pavement tar sealants (“Pitch,” 1998). It is used as an anti-itch treatment for psoriasis and similar skin conditions as well as a bonding agent in many of these products. "[C]oal tar can be treated differently for different purposes" (Singh et al., 2015), therefore it has proven useful for many products.

Coal tar is used as the main ingredient in some pavement sealcoats used for pavement maintenance. Pavement sealcoats have been widely used throughout the U.S. as they are a relatively inexpensive yet effective way to seal and coat pavement to enhance its appearance and repel and seal water from the surface. Coal tar-based sealcoats contain water, clay, emulsifiers, and a binder of asphalt, coal tar pitch, and cut-back oil (Boyer & Doolin, 1999). However, many researchers have found significant environmental concerns with coal tar-based sealcoats.

2.2 Coal tar-based sealcoat and PAHs

Coal tar is used as the main ingredient in some pavement sealcoats utilized for the maintenance of dry and damaged pavement. “The coal-tar varieties [of sealcoats] typically are 15-35% coal tar, a known carcinogen with extremely high concentrations of PAHs” (Van Metre et al., 2009). These sealants sit on the surface of the pavement and are subjected to wear, causing possible air emissions and dust buildup that can be carried into the surrounding environment by humans, animals, vehicles, and in storm water. According to research done by Van Metre et al., “particles in runoff from parking lots with coal-tar-based sealcoat might account for the majority of stream PAH loads” (Van Metre et al., 2009). Acute or chronic exposure to PAHs through contact with contaminated air or substances has been linked to cancer, genetic

mutation, and development problems in humans (ATSDR, 2002).

In 2005 and 2010, Drs. Van Metre and Mahler found that TPAH concentrations in sediment samples averaged around 10-50 mg/kg in reservoirs and lakes from six metropolitan areas with a range of 2.79 to 224 mg/kg (Van Metre & Mahler, 2005). These high concentrations are in dramatic contrast to relatively undisturbed sediments taken from Grand Teton National Park (WY), where the maximum TPAH concentration was found to be 0.48 mg/kg (Rhea et al., 2005). Higher concentrations of PAHs are cause for concern, as it is reported that TPAH concentrations above 22.8 mg/kg in sediment are likely toxic to sediment-dwelling organisms (MacDonald et al., 2000).

PAHs are also deposited in urban sediment from car exhaust, lubricating oils, gas, tires, wood and coal smoke, pavement, and soot (Mahler et al., 2012). However, research has linked coal tar-based sealcoats with higher TPAH concentrations within sediment in streams adjacent to coated areas. The EPA reported that PAHs can be released into streams after application of these sealants before the coat fully sets (US EPA, 2011). PAHs are also contributed from the weathering and abrasion of the sealant over time (Mahler et al., 2005). Coal tar-based sealcoats have since been reported to contribute more than half of TPAH contamination in sediments from streams and lakes in central, southern, and eastern U.S. (Van Metre & Mahler, 2010).

In a study done by Scoggins et al., streams near sealed parking lots were tested for PAH concentrations both upstream and downstream of the lots. The results showed, “PAH concentrations in suspended sediment in runoff from coal-tar-sealed lots (mean = 3500 mg/kg TPAH) are 65x higher than concentrations in suspended sediment in runoff from unsealed lots”. All seven of the carcinogenic PAHs in Table 1 were higher in concentration downstream from parking lots coated in coal tar-based sealcoats (Scoggins et al., 2007). In similar studies done by Van Metre et al., coal tar-based sealcoated lots showed “considerable difference[s]” in PAH levels when compared to asphalt lots. These differences were concluded to be from the coal tar specifically, as they “cannot be attributed to other sources of PAHs, such as fallout of industrial

emissions, exhaust particles, tire-wear residue, or leaking motor oil, because PAHs from such sources are equally likely to occur on both unsealcoated and sealcoated lots" (Van Metre et al., 2009).

PAHs have also been shown to be present at higher levels in household dust samples adjacent to coal tar-based sealcoated pavement. Dust samples were taken in homes near coal tar sealcoated pavement as well as in homes adjacent to asphalt pavement without sealcoat. In the homes adjacent to coal tar sealcoated pavement, 43.5 mg/kg of the seven PAHs classified as probable human carcinogens (B2 PAHs) were found in the household dust, nearly 15x more than the amount in the homes adjacent to pavement without sealcoat. Assuming a non-dietary dust ingestion of 0.027 g/d and 0.101 g/d, the study found that PAHs were ingested in much higher doses not only when compared to other homes, but the ingestion also exceeded published recommended PAH doses. These findings suggest "that house dust in residences adjacent to coal-tar-sealed pavement might represent a primary and biologically relevant exposure to B2 PAHs" (Williams et al., 2012).

Due to the proven mobilization of PAHs in coal tar-based sealcoats from the pavement to the environment around it and the potential human health effects, coal tar-based sealcoats have been banned within 9 states (either state-wide or parts of the state) and use restricted within 15 (Ennis, 2013). The first ban occurred in Austin, TX in November of 2005, but the only states with statewide bans are Washington and Minnesota. These bans prohibit the use and restrict sales of coal tar pavement products (Van Metre & Mahler, 2014). States and territories with coal tar-based sealcoat bans within some districts include Texas, Wisconsin, New York, Washington, Illinois, Maryland, Massachusetts, Minnesota, and the District of Columbia (as seen in Figure 2 below) (Ennis, 2013).

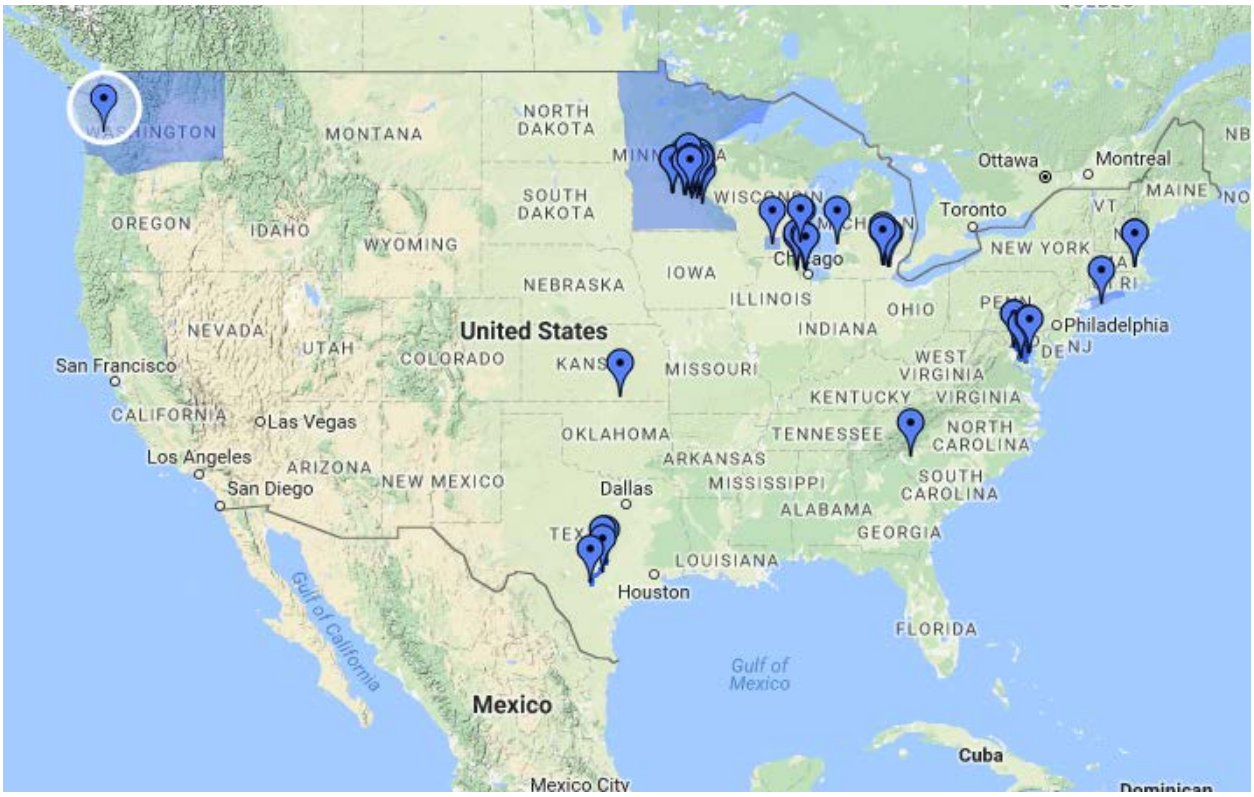


Figure 2: Bans on coal tar products in the US, adapted from Ennis, 2013.

In response to the many resources that the USGS provided linking coal-tar based sealants to carcinogenesis, the trade group "Pavement Coatings Technology Council" (PCTC), has commissioned post publication comments and submitted multiple Information Quality Act Requests for Correction (RfC) to substantiate the claim that occupational or incidental exposure to PAHs are not proven to promote carcinogenesis (Ennis, 2016). PCTC requested to have the peer-reviewed journal article published by the American Chemical Society *Parking Lot Sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons* (Mahler et al., 2005) retracted, stating that there was, "clear evidence that the [paper's] findings are unreliable" due to unreproducible data as well as missing data. The council also requested that the EPA correct two of their publications on coal tar products as they posed a bias. This request was denied by the EPA (Beauvais & Burke, 2016). Therefore, coal tar-based sealants are still widely accepted as contributors to higher PAH levels and subsequent health effects. It is important to note that the research done by Mahler et al. and other researchers (cited here) was published in peer-

reviewed scientific journals.

2.2.1 Pavement rejuvenators

Similar to sealcoats, pavement rejuvenators are utilized in an attempt to lengthen the lifetime of a pavement installation as well as increase serviceability for a period of time. The US Army Corps of Engineers (COE) has evaluated the use of both sealcoats and rejuvenators on airfields within their jurisdiction. The COE describes both sealcoats and rejuvenators as "rejuvenators" in their research, but in general they prefer the use of a true rejuvenator due to the risk of a sealcoat flaking off and producing what the COE refers to as foreign object damage (FOD). While there are many proprietary rejuvenators on the market, the COE evaluated rejuvenators with coal tar, asphalt emulsion, and petroleum bases. In the 2003 study, seven of the eleven tested rejuvenators were of a coal tar-base (Shoenberger, 2003). This project focused on one coal tar-based rejuvenator that was not used in the 2003 study, marketed as Pavement Dressing Conditioner (PDC).

In 1964, Edward McGovern, an employee of Koppers Company, Inc., filed for a patent protecting his invention of a specific composition of a coal tar-based pavement sealer (McGovern, 1966). Koppers Company is a distiller of coal, producing coal tar in coke ovens to refine chemicals such as creosote, which can be used to coat/impregnate telephone poles to extend their life ("About Koppers," 2017). McGovern used a similar chemical for his composition that was also produced by Koppers in coke ovens: coal-tar pitch. McGovern titled his chemical composition, "pavement dressing conditioner," and claimed that unlike regular coal tar sealants, his composition also penetrated the surface of the pavement to replace bitumens that have been lost over time and due to use. The patent's language describes aged bituminous asphalt pavement in a way that conjures up an image of a dried sponge: cracked and shrunken. The conditioner was, in a way, like water to an old sponge; replacing those shrunken pores with a chemical compound that mimics the composition of asphalt when it cures (McGovern, 1966).

There has been much interest in the possibility of extending the life of aged pavement with rejuvenator products, in spite of the lack of evidence pertaining to the environmental and health safety of the products. One manufacturer's claims include:

> *"Unlike traditional sealcoats which coat the surface and do nothing to repair or protect the pavement, PDC literally penetrates the asphalt to chemically rejuvenate, revitalize and protect the asphalt by replacing the tars and oils lost due to oxidation. Not only does PDC beautify your property with an even black finish, but also extends the life of your pavement by 3 to 5 years with each application.*
>
> *Will significantly lower viscosity, increase penetration, lower softening point, and increase the ductility of the binder without disturbing the binders' ability to retain aggregate and not significantly lower skid resistance."*
>
> *("PDC - Pavement Dressing Conditioner - Asphalt Rejuvenator," 2017)*

According to the most recent patent on PDC, held by KAE pavement consultants, the product can contain 70-95% coal tar components, including up to 35% naphtha solvent. Both components are comprised of persistent chemicals and coal tar is a known carcinogen. These components are present in higher concentrations than found in typical commercial coal-tar based sealants. Based on the patent information, the largest difference between the two products, sealants and rejuvenators, is the location in which the compound is expected to cure (McGovern, 1966).

CHAPTER 3: METHODOLOGY

The goal of this project was to assess the mobilization of PAHs from an applied coal tar-based pavement rejuvenator to the surrounding environment. This research was conducted in a neighborhood in Pomfret, Connecticut where a coal tar rejuvenator was recently applied by

sampling dust on the pavement surface and catch basin sediment. Gas chromatography was utilized to quantify total PAHs in the dust and sediment samples.

3.2 Objectives

1. Quantify the total PAH concentration in the surface coating on pavement treated with a coal tar-based rejuvenator.

2. Investigate the PAH mobilization from a pavement treated with a coal-tar based rejuvenator into catch basin sediment samples.

3. Recommend future investigative avenues to elucidate environmental impacts of coal tar-based rejuvenators.

3.3 Sample Collection Procedures

For this investigation the following procedures were developed for collecting dust and sediment samples at a study site in Pomfret, Connecticut where a coal tar-based rejuvenator was applied in late July 2016 and a reference site: a local road with similar characteristics that has been left untreated since pavement installation.

3.3.1 Pavement Surface Dust Samples

Dust samples were collected by sweeping 3 m by 3 m pavement areas at each sampling location with clean hand brooms and dustpans (see Figure 3).

Figure 3: Surface dust sample collection procedure.

The 9 m^2 area was marked in each sampling location on the pavement, and all dust was carefully swept into plastic dustpans (see Figure 3).

Figure 4: Dust sample collection.

The dustpans and hand brooms shown in Figure 4 were used once for each sample. The

samples were transferred to clean glass jars with screw caps, which were immediately labeled, and the samples recorded in sample logs. Samples were stored in the dark at 4 C until shipping to the USGS for analysis. Samples were also taken from the reference site to provide background contaminant levels. The autumn samples were taken on October 19, 2016.

Sampling was limited to drive lanes, and areas with petroleum stains and heavy sediment were avoided in an attempt to eliminate any contamination from other origins. One sample was collected from each cul-de-sac and three samples were collected from Longmeadow Rd, approximately equally spaced apart (see Figure 5). One sample was collected from the reference site (Anderson Rd., Pomfret CT). Nitrile gloves were worn for all sampling.

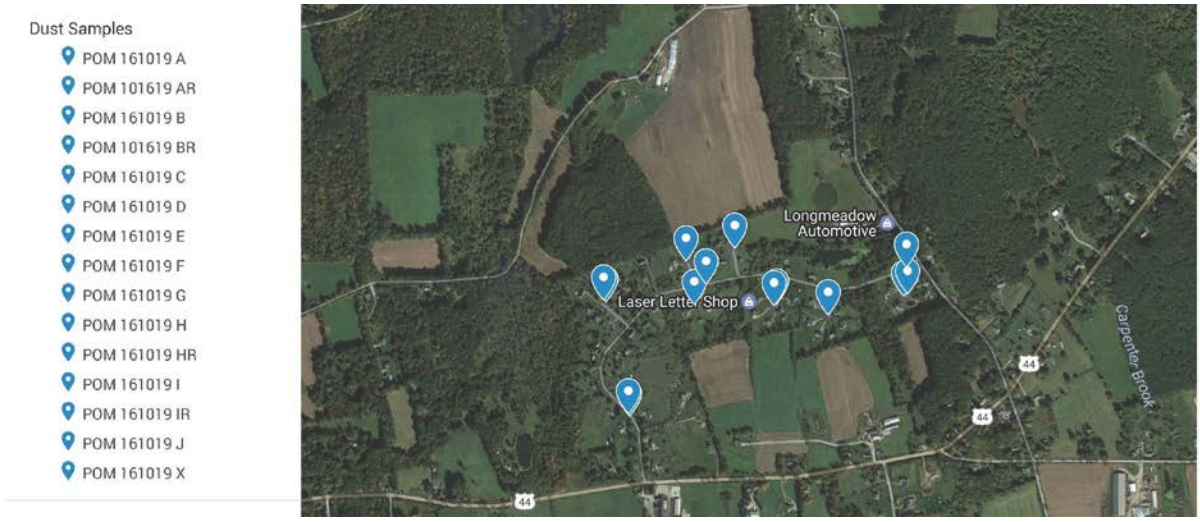


*Figure 5: Surface dust sample locations (any sample labeled *R is a replicate sample).*

The surface dust samples were submitted to the USGS for chemical analysis, but results were not received by the date of this final report (April 27, 2017).

3.3.2 Road Surface Coating Samples

Samples of the coating material were removed from the pavement by scraping with steel tools. Samples were taken on September 14, 2016 adjacent to 1 Sanda Circle. The material was

collected in glass bottles, which were labeled and stored at 4 C until analysis. Nitrile gloves were worn for all sampling.

3.3.3 Sediment Samples from Adjacent Areas

Sediment samples were taken in a swale, at a location down gradient of a catch basin outfall where sediment/dust/solids deposition was expected. Samples were collected using a syringe modified by cutting the rounded top and needle off, leaving the front of the syringe fully open (see Figure 6).

Figure 6: Sediment sample syringe and technique.

The open end of syringe was pushed into the sediment in a perpendicular direction while withdrawing the plunger, effectively filling the syringe with sediment. This syringe was then emptied by depressing the plunger, releasing the sediment into clean glass collection vials that were labeled, itemized and sent with detailed collection logs to the USGS National Water Quality Laboratory for full analysis (results were not received by the date of this final report). Syringes were cleaned between samples by rinsing with methylene chloride and then purified water. Purified water was produced with a Thermo Scientific Barnstead Nanopure Life Science UV/UF system.

3.3.4 Catch Basin Sediment Samples

Sediment from the catch basins was collected with a sampling apparatus which incorporated an extendable handle to allow reaching samples in the bottom of the catch basins. The sampling apparatus held plastic sampling containers (see Figure 7).

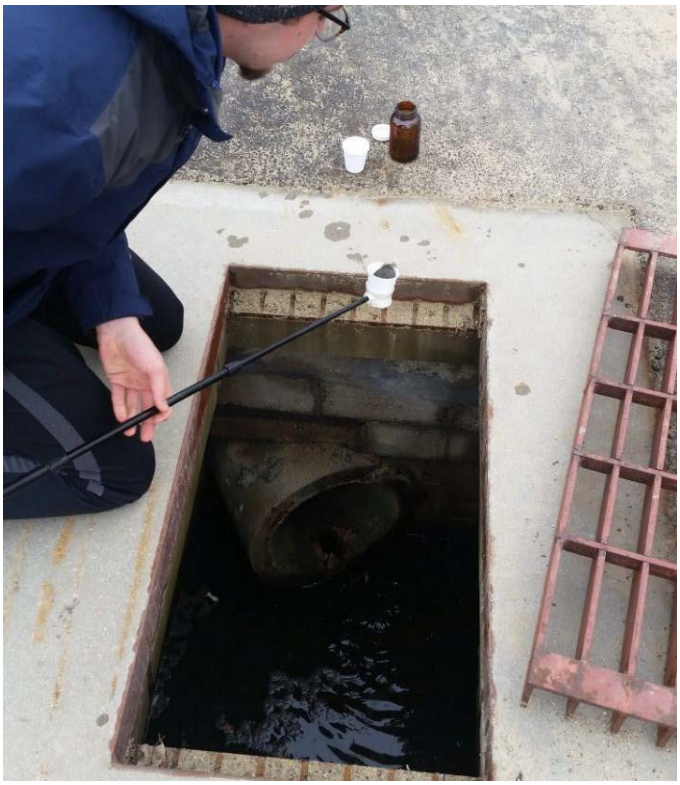


Figure 7: Catch Basin Sampling.

Catch basin samples were collected monthly (November - February) from the following locations:

CB0: Reference location in the center of the cul-de-sac at the end of Anderson Road, Pomfret Center, CT
(41.847031, -71.939975) (see Figure 8)

CB1: Adjacent to 71 Longmeadow Drive, Pomfret, CT
(41.900868,-71.941063) (see Figure 9)

CB2: Adjacent to driveways of 5 and 7 Fairview Circle, Pomfret, CT (41.902129, -71.941310) (see Figure 9)

CB3: Adjacent to properties 3 and 5 Ruth Circle, Pomfret, CT (41.901840, -71.937756) (see Figure 9)

CB4: On the southern side of Longmeadow Drive, between Dolores Circle and Sanda Circle, Pomfret, CT (41.902753, -71.935785) (see Figure 9)

CB5: On the northern side of Longmeadow Drive, across from Margaret Circle, Pomfret, CT (41.902424, -71.932901) (see Figure 9)

See Figure 8 for an aerial view of the reference location and Figure 9 for locations of the Longmeadow Estate catch basins. Use the following map key to correctly identify the locations:

Figure 8: Anderson Road Catch Basin Location.

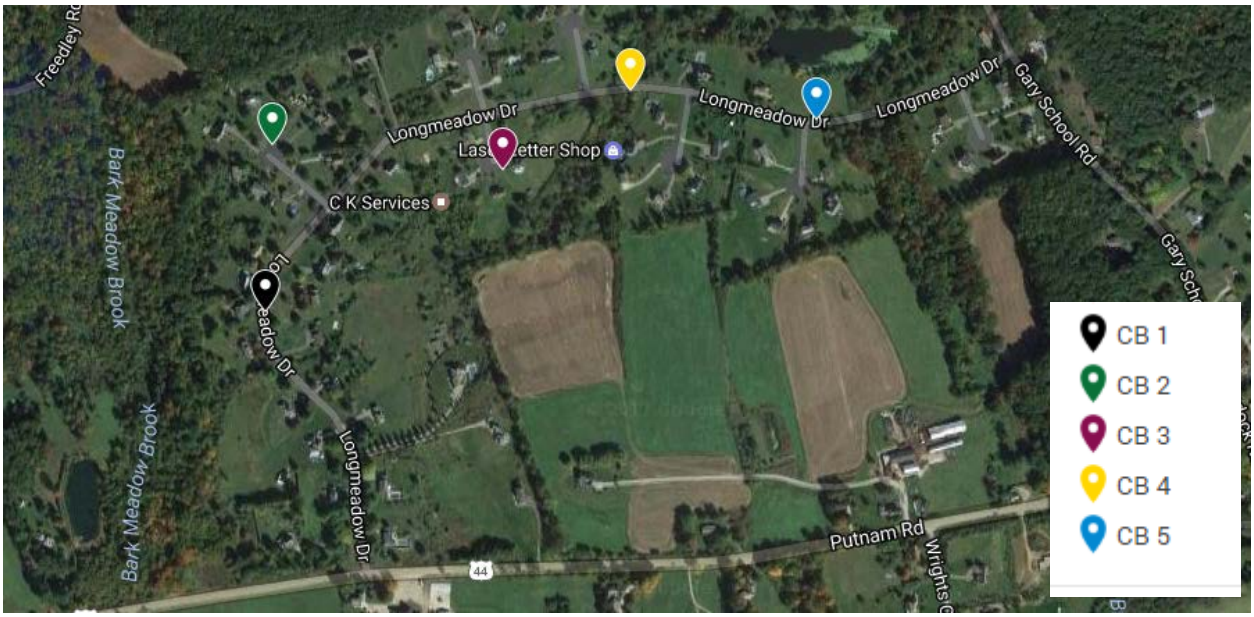


Figure 9: Longmeadow Drive Subdivision Catch Basin Locations.

3.4 Contaminant Analyses

3.4.1 Sediment and surface coating sample preparation

One g of each sample was mixed with 10 mL of MeCl (Fisher Scientific, Fair Lawn, NJ) in a clean glass vial with a screw cap. These vials were then set in a sonication bath for 5 minutes to encourage chemical extraction and a homogeneous mixture. Mixtures were then transferred using a syringe and filtered through single use RC- membrane filters with 0.2μm pores into 1.5 mL vials to be analyzed using a gas chromatograph.

3.4.2 Gas chromatography analysis

An Agilent Technologies (Wilmington, DE) 6890 gas chromatograph with a 7683 Series Injector and AutoSampler was used to analyze the prepared samples. An Agilent Technologies 13-5536 (30 m x 0.25 mm) column was used (Wilmington, DE). The oven temperature was 35 C for 4 minutes, ramped to 50 C with a heating rate of 3.00 C/min, and then ramped to 290 C with a

heating rate of 8.00 C/min, and kept for 3 minutes at 290 C. The temperature of the detector was 300 degrees C. An injection volume of 2.0 µL was injected splitless with helium carrier gas. For full instrument operational information, refer to Appendix A. A PAH standard was obtained from Ultra Scientific (North Kingstown, RI) and was used for preparing a standard curve (standard chromatogram shown in Appendix B).

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Chemical Analysis of Coal Tar-Based Rejuvenator Coating on Pavement

An understanding of the chemical signature of rejuvenator applied to pavement is important to comprehend the possible environmental and health effects of the mobilization of its ingredients. The coal tar-based rejuvenator applied to the study site, Pavement Dressing Conditioner (PDC), has:

> "[A] sealing and rejuvenating composition for bituminous and concrete surfaces comprising 50-60% by weight of topped coke oven tar... 20-35% by weight coal tar solvent having a boiling range of 95-250° C and 15-30% by weight of a mixture of di-, tri- and tetracyclic aromatic compounds" (McGovern, 1966).

This description indicates that this proprietary pavement rejuvenator is comprised of many materials that are heavy in total PAHs (TPAH), as are other coal tar-based pavement products. In fact, according to research published by Mahler et al. in 2010, coal tar-based sealants contain >50,000 mg/kg TPAH, and dust from coal tar-sealed parking lot surfaces has been found to contain a mean of 1,230 mg/kg TPAH (Mahler et al, 2010).

Our initial results were well correlated with TPAH values obtained by Mahler et al. Chemical

analysis of 1% coal tar in a methylene chloride matrix was conducted and resulted in TPAH >42,000 mg/kg. Chemical analysis of pavement surface coating samples exhibited a mean of 8,225 mg/kg TPAH with a 95% confidence interval of 466 mg/kg. Figure 10 below shows a chromatogram of the surface sample analysis.

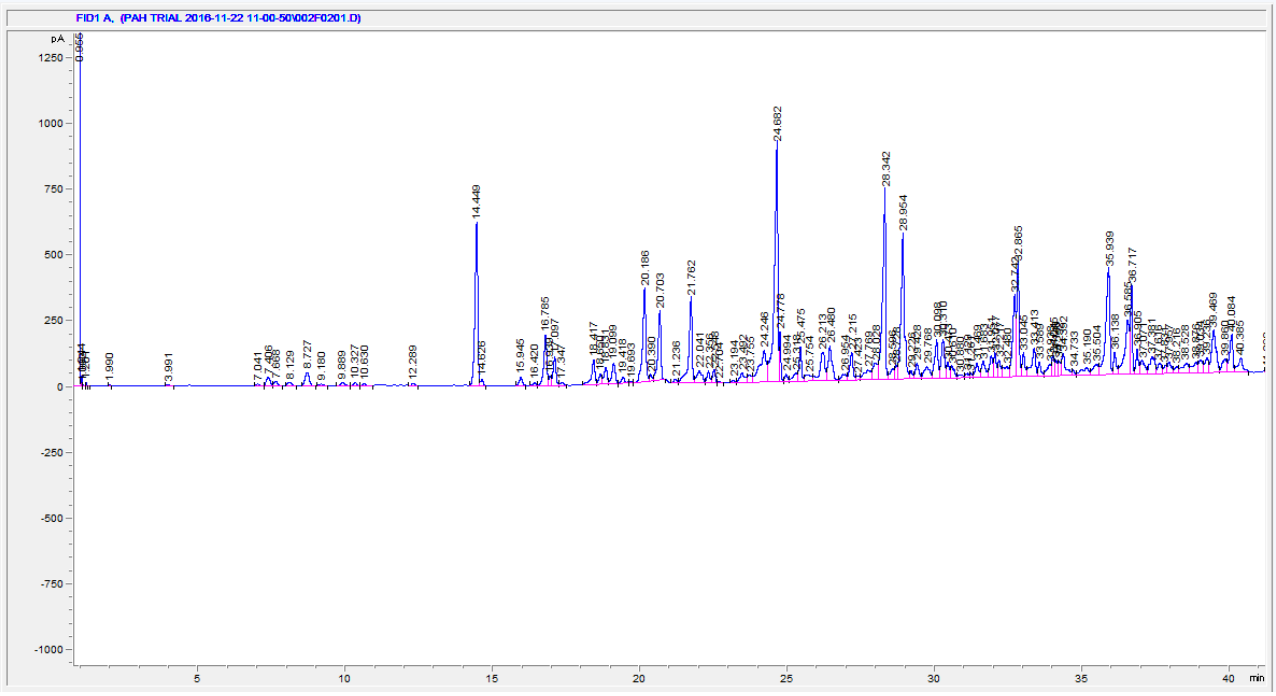
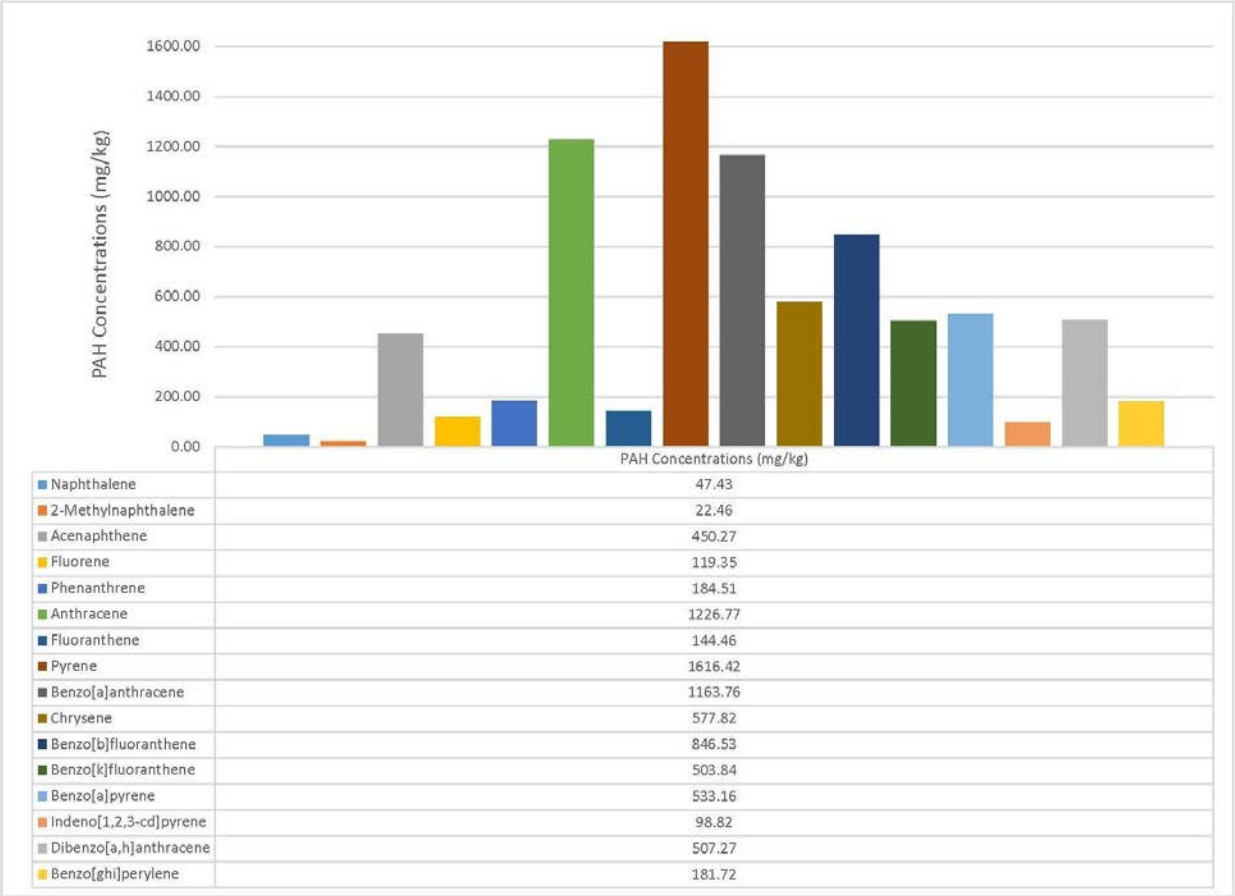


Figure 10: Sample chromatogram of pavement surface coating sample.

In Figure 11 below, the individual PAH (average of 3 runs) concentrations for sixteen EPA priority pollutant PAHs are itemized for the pavement surface coating sample taken from the study site.



	PAH Concentrations (mg/kg)
Naphthalene	47.43
2-Methylnaphthalene	22.46
Acenaphthene	450.27
Fluorene	119.35
Phenanthrene	184.51
Anthracene	1226.77
Fluoranthene	144.46
Pyrene	1616.42
Benzo[a]anthracene	1163.76
Chrysene	577.82
Benzo[b]fluoranthene	846.53
Benzo[k]fluoranthene	503.84
Benzo[a]pyrene	533.16
Indeno[1,2,3-cd]pyrene	98.82
Dibenzo[a,h]anthracene	507.27
Benzo[ghi]perylene	181.72

Figure 11: Average individual PAH concentrations in pavement surface coating samples.

4.2 Mobilization of PAHs into the Site Catch Basins

We hypothesized that the PAHs in the rejuvenator coating would mobilize in two ways: initially through volatilization into the atmosphere, and after curing, through abrasion of the surface coating producing small, mobile flakes.

In an effort to trace and quantify the mobilization of TPAHs from the rejuvenator treated pavement, five catch basins in the study site were chosen as initial sampling locations to collect sediment for analysis. Three catch basins were located approximately equidistant along the main road and two were located at the end of cul-de-sacs along the main road. The results of the initial sampling (one sample per catch basin per month for three months) is shown in Figure

12.

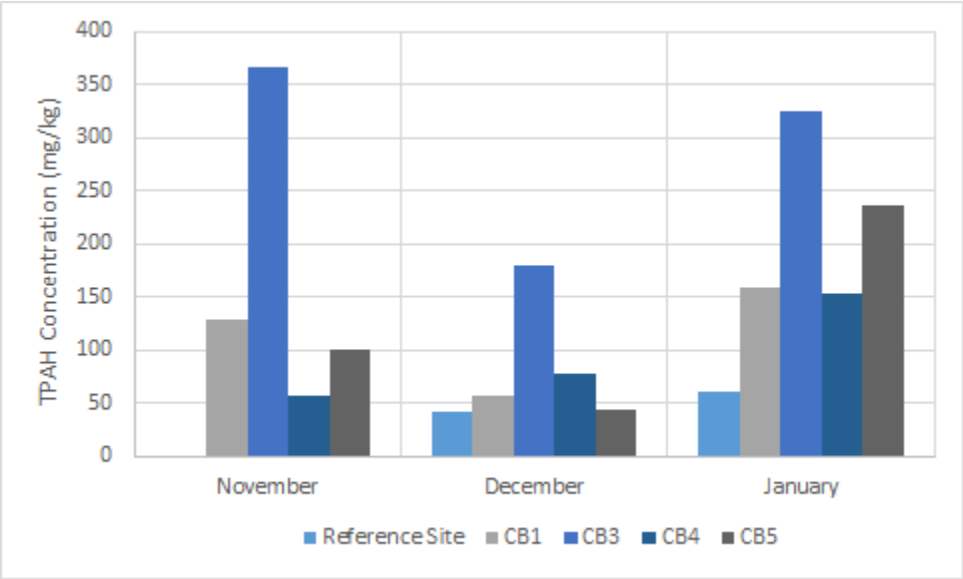


Figure 12: TPAH concentrations in initial catch basin samples.

Catch basin 2 was eliminated from further evaluation due to lack of sediment sample at the bottom of the basin. Catch basins 3 and 5 were chosen for further study as they were considered representative of the two types of catch basin locations at the study site: one along the main road in the development, and one on a cul-de-sac. In addition, catch basin 3 had a similar collection area (pavement surface area) when compared to the reference site (see Appendix C for surface area calculations).

As further study focused on catch basins 3 and 5, a minimum of three samples were analyzed for each catch basin at each sampling time to provide statistical comparisons. Results for these samples contrasted with the reference sample are displayed in Figure 13.

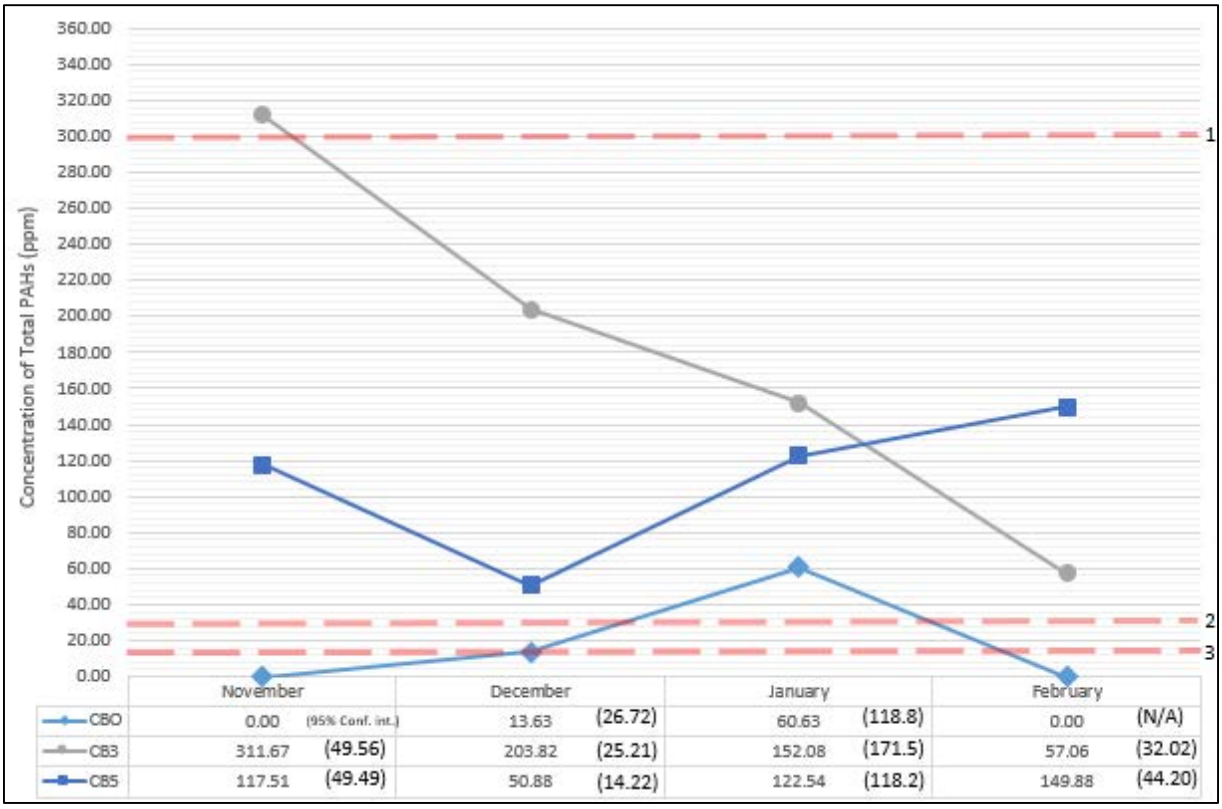


Figure 13: TPAH concentrations in catch basin sediments at the study site over the test period.

1. *Fatal chronic exposure (amphibians), Growth and development affected (benthic organisms) (Bryer et al. 2006).*
2. *Growth and development affected (amphibians) (Bryer et al. 2010).*
3. *Likely toxic (benthic organisms) (MacDonald et al. 2000).*

As shown in Figure 13, higher TPAH concentrations within the catch basin sediment samples compared to the reference site suggests that the PAH-containing rejuvenator was mobilizing from the surface coating on the pavement into stormwater runoff, eventually co-mingling with catch basin sediments. It should be expected that abrasive wear from tire friction, abrasion from sand applied for traction in winter events (typically hard, angular silica), abrasion from snow plowing, etc. would dislodge surface material. The potential effects from long-term wear are shown in Figure 14, which on the left shows the coated pavement at the study site after application of the rejuvenator, and on the right showing bare aggregate at the reference site. Clearly, any coating would eventually wear off to show aggregate.

Figure 14: Comparison of pavement surface at study site (left) and reference site (right).

This data correlates with research completed by others who showed mobilization of PAHs from treated pavements. This includes studies by Scoggins et al. where PAHs were found in high concentrations downstream of sealcoated lots and studies by Maher and Van Metre et al. where PAHs were found in higher concentrations in lakes and reservoirs by urban areas with sealcoat use. Though households were not tested for PAH concentrations in this study, these findings could suggest that a rejuvenator could contribute to PAHs in dust within households the same way sealcoats were found to in the study done by Williams et al.

4.3 Discussion

In a study done by Bryer et al. in 2010, the effect of coal tar-based sealants on macroinvertebrates in streams in Austin, TX was explored through controlled exposure to low, medium, and high PAH levels (control of 0.1, low of 7.5, high of 300 mg/kg). Sterile soil was exposed to dried coal tar pavement for 24 days at which point sediment-dwelling benthic macroinvertebrates were added to the environment. A clear trend of reduction in macroinvertebrate abundance with increasing PAH concentrations from coal tar was observed (Bryer *et al*., 2010).

In other research conducted by Bryer et al. in 2006 investigated the effects of PAHs in streams and stormwater runoff on amphibians, with *Xenopus laevis* (African clawed frog) as a study group. Fertilized eggs were exposed to 0, 3, 30, or 300 mg/kg of PAHs in contaminated water samples to determine developmental, survival, and growth effects. All frog eggs exposed to 300 mg/kg died within six days, while groups exposed to medium level contamination showed significant developmental delays and stunted growth within 14 days. It is important to note that the difference between the medium (30 mg/kg) and high (300 mg/kg) exposure concentrations is extreme, leaving the effects of intermediate concentrations (50-250 mg/kg) on aquatic life unknown (Bryer et al., 2006). This research substantiated Monson et al.'s 1999 findings that 2–10 mg/kg of fluoranthene was lethal to a community of northern leopard frogs, when combined with simulated direct sunlight (Monson et al., 1999). The first research done with northern leopard frogs was conducted in 1995, when Sadinski et al. found that exposure to 248 nM of benzo(a)pyrene produced tadpoles that were smaller and took longer to mature than the controls in the same experiment (Sadinski et al., 1995).

Streams below coal tar-sealed parking lots displayed increases in PAH concentrations within the sediment in a study done by Scoggins et al. These increases were found to have negative effects on richness, taxa, and density within downstream aquatic communities. It was found that two types of habitat were negatively affected; suggesting that differing PAH concentrations will yield negative consequences regardless. It was also found that hot spots in the study streams were having toxic effects on the benthic community (Scoggins et al., 2007).

Vandenbrouck et al. investigated the effects of pyrene and fluoranthene (two PAHs that coal tar contains) on planktonic crustaceans. The subjects were exposed to the single compounds or a binary mixture to observe the difference in reaction. It was found that reproduction of the crustaceans was negatively affected by both compounds and mixtures, suggesting that single compounds and binary mixtures pose possible threats to crustaceans in environments containing these PAHs (Vandenbrouck et al., 2010).

The results of this research at the subject study site where the pavement was coated with coal tar-based rejuvenator show adjacent catch basin sediment with TPAH concentrations of at least 50 mg/kg TPAH and as high as 300 mg/kg TPAH. This rationalizes the concern for aquatic life within benthic and amphibious communities downstream from pavement treated with coal tar-based rejuvenators.

4.4 Limitations

As shown by Figures 11 and 12, the PAH concentrations of all samples taken from catch basins adjacent to pavement treated with the coal tar-based rejuvenator were all higher than concentrations in the reference catch basin at every sample time. Still, there are multiple factors to consider when discussing the nuances in concentrations from month to month.

Since November, TPAH concentrations in the catch basin sediment have been varied. TPAH concentrations in CB5 were relatively constant while there was a significant decrease in CB3 sample concentrations from November to December, possibly explained by the sudden increased use of sand and salt on the road during inclement weather in the winter. The subdivision pavement was treated with a sand and salt mix during snow storms and freezing weather; total sand use in the Longmeadow Drive subdivision in the winter season totaled “not more than 5 tons of 2:1 sand:salt mixture” (Baldwin, 2017). The application of sand would be expected to dilute the TPAH concentrations in the samples: more inorganic (sand) material was being washed into the catch basins, causing a decrease in TPAH concentration (yet still above the reference site concentrations). Figure 15 clearly shows this dilution as displayed by the high concentration of black particles seen in November samples when compared to the low concentration found in February samples. Figure 16 displays the high amounts of sand present at the study site in the month of January and Figure 17 showing the excess sand remaining at the study site in April.

Figure 15: Sample contents in November (left) before sand use vs February (right) after sand use.

Figure 16: Excess sand at study site in January.

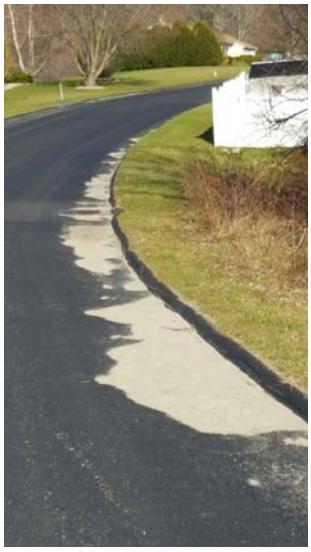


Figure 17: Excess sand still remaining at the study site in April.

It was also noted that after the first month, PAHs with lower molecular weights were no longer observed in the chemical analysis. Naphthalene, 2 methylnaphthalene, acenaphthene, fluorene, and phenanthrene were all present in the first month's samples, but were not present in any detectable concentrations in the months following. One example can be seen in Figure 18 below; the preliminary data for CB 3 from a sample taken in October clearly shows high concentrations of the first five PAHs, but the chemical analysis for the sample taken in November had undetectable levels of these lightest molecular-weight PAHs.

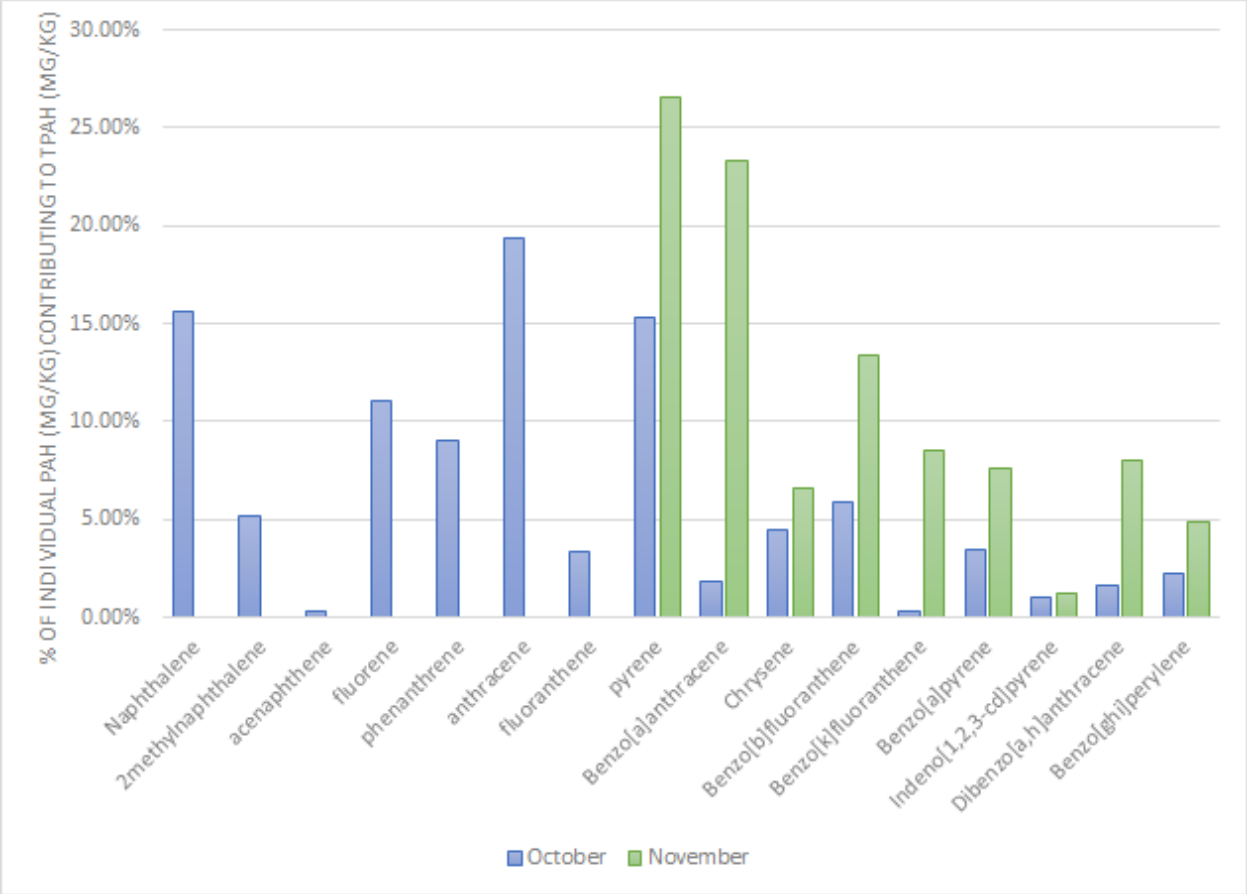


Figure 18: Catch Basin 3 (CB3) percentage of individual PAH concentrations contributing to TPAH concentrations in October and November.

One possible hypothesis for this change in chemical signature is volatilization into the atmosphere, likely in parallel with photolysis reactions. This raises concerns not only for the residents of neighborhoods within the first months of application, but also the exposure that the professionals might experience during the application process.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Recommendations for Future Research

Future research into the extent of PAH mobilization from coal tar-based rejuvenators is

necessary to quantify the dangers of using PDC in residential neighborhoods. Elucidation of the mechanisms of mobilization is also necessary to understand PAH behavior originating from rejuvenators. This could be accomplished through lab based trials designed to show the effects of wear, sand, snowplowing, etc. Side-by-side comparison of coal tar based rejuvenators to asphalt and other types of rejuvenators (e.g. bio based) could provide clearer insight into the environmental effects of these rejuvenators. Lab testing could also quantify the amount of volatilization that contributes to the loss of lighter PAHs in the early stages of application. This is needed to understand possible emissions of the product and could explain decreases over time in the TPAH concentrations found in this study.

Sieve analysis could provide answers to why there was a decrease in TPAH concentration in winter months. If sand and rock salt could be the cause, sieving them out could confirm or refute this. We would also recommend testing the effect of snow plowing to determine if plowing aids in PAH mobilization. Furthermore, chemical analysis of the water in the catch basins would provide insight into whether PAHs are suspended and/or bioavailable, and if soluble contamination is also being formed.

We believe there may be PAH contributions from sealcoat used on driveways adjacent to the reference site. To ascertain the effects of these sealcoated driveways we suggest testing multiple reference sites to get a better understanding of PAH levels expected at other sites. The PAH concentrations in the pavement dust on neighborhood driveways should also be quantified to determine their input to possible runoff into catch basins.

Research into the size fractionation of real samples (containing PAH flakes and sand/sediment) is needed to determine sample heterogeneity. Our samples show high deviation between replicates, suggesting the presence of “hot spots” in the samples. This could be from flakes of the product being abraded and deposited into the catch basins. Increase in number of replicates will also reveal this heterogeneity and possibly alleviate the high deviations presented in our data.

Photolysis could contribute to the change in chemical composition of the product, therefore we recommend observing changes in PAH concentrations in the rejuvenator coating subjected to sunlight. This could be done artificially in a lab or through a controlled environment and could provide insight into whether the product is more or less harmful when exposed to light.

5.2 Design of a Bioretention Feature to Address PAH Mobilization from Rejuvenator Treated Pavement

Prabhukumar and Pagilla established best management practices (BMP) that can be employed for the treatment and control of PAHs in stormwater runoff, namely seven filtration control measures that can be used to treat water leaving a stormwater system at its endpoint (Prabhukumar & Pagilla, 2010). Of those BMPs, bioretention areas are purported to reduce PAH mass loads by an average of 87% (Diblasi et al., 2009).

Bioretention facilities blend into landscaped areas to reduce pollutants in stormwater runoff. Within a vegetated bioretention area, several layers include woody and herbaceous plants, mulch, soil, and a sand bed. Pollutants are transformed, sequestered, or filtered out by the plant and soil system as the rainwater seeps through each layer. Typical maintenance for bioretention filters includes mowing grass, occasional removal of sediment (especially at inlets), re-vegetation as necessary, and removal of any debris (Prabhukumar & Pagilla, 2010). In this particular installation, it is recommended that filter media be removed and replenished at a regular interval to combat the persistent nature of PAHs and to effectively remove those PAHs and/or azaarenes that may still mobilize from the filter. A detailed specification of a bioretention area is depicted in Figure 19 below.

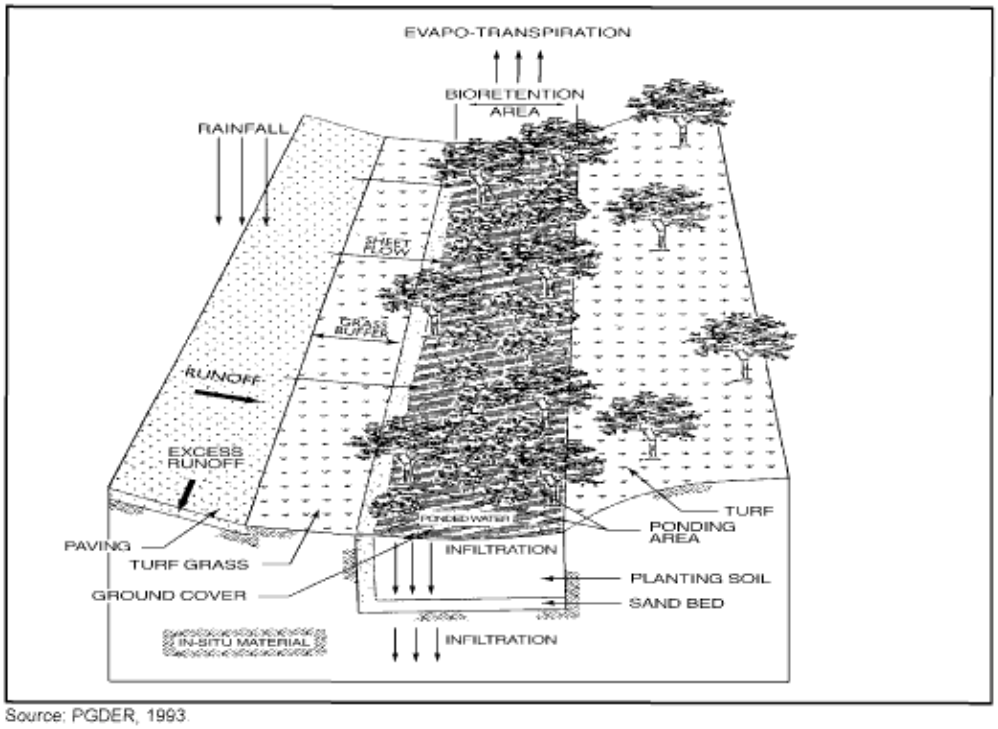


Figure 19: Bioretention area detail (PGDER, 1993).

The US EPA recommends a bioretention facility that is at least 4% of the impervious area that contributes to the offsite flow in a given catchment area (Impervious area * 0.04 = Design area). Using CB 5 on Longmeadow Drive, which has a catchment area of around 38,000 sq.ft. of impervious surface, a bioretention facility at 1,520 sq. ft. would be sufficient in treating the outflow for water quality purposes. Figure 20 portrays a potential location for this design area (60 ft x 30 ft) in order to remediate potential PAH outflow from CB 5 into the nearby Medbury pond.

Figure 20: Bioretention area design location plan.

Based on a typical breakdown of costs associated with installing bioretention facilities done in Prince George's County, Virginia in 2002, total costs for installation within a residential subdivision can range from $3790 to about $8000 depending on the size and difficulty of installation (PGDER, 1993).

Additionally, catch basin inserts and filters can be retrofitted to existing catch basins to capture and treat the most frequent rainfall events with a PAH removal rate in the range of 80-99.4%. Catch basin inserts are an effective means of reducing non-point source pollution, but require frequent routine cleaning, often after every storm to maintain their effectiveness (Prabhukumar & Pagilla, 2010). Catch basin inserts are readily available and range from $30 - $60 per unit.

5.3 Summary

Coal tar-based sealcoats have been linked to toxicity and carcinogenesis in freshwater

communities downstream from application sites. This research substantiates the hypothesis that coal tar-based rejuvenators mobilize in a similar fashion and could potentially cause environmental and health concerns for communities adjacent and downstream in relation to application sites. Samples from catch basins adjacent to pavement coated with a coal tar-based rejuvenator showed TPAH concentrations significantly above levels from a reference site, and concentrations concerning for aquatic life. There are other alternative products to consider when attempting to rejuvenate asphalt-based pavements with a lower TPAH concentration, but the environmental effects of any application should be taken into account before use. We hope that our research can educate and guide further discussions regarding the use of coal tar-based products in residential areas.

References

About Koppers. (2017). *Koppers, Inc*. Retrieved 17 April 2017, from http://www.koppers.com/pages/about-koppers

Baldwin, Craig, Pomfret First Selectman, personal correspondence on April 19, 2017.

Beauvais, J., & Burke, T. A. (2016, January 19). EPA response to RFC [Letter to Anne P. LeHuray]. United States Environmental Protection Agency, Washington, D.C.

Boyer, D. C., & Doolin, P. K. (1999). *U.S. Patent No. US6361591 B1*. Washington, DC: U.S. Patent and Trademark Office.

Bryer, P. J., Elliott, J. N., & Willingham, E. J. (2006). The Effects of Coal Tar Based Pavement Sealer on Amphibian Development and Metamorphosis.

Bryer, P. J., Scoggins, M., & McClintock, N. L. (2010). Coal-tar based pavement sealant toxicity to freshwater macroinvertebrates. *Environmental Pollution*, *158*(5), 1932–1937.

Coal Tar and Coal Tar Pitch. (2017). Retrieved January 1, 2017, from https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/coal-tar

Diblasi, C. J., Li, H., Davis, A. P., & Ghosh, U. (2009). Removal and fate of polycyclic aromatic hydrocarbon pollutants in an urban stormwater bioretention facility. Environmental Science and Technology, 43(2), 494–502. http://doi.org/10.1021/es802090g

Destructive Distillation of Coal. (2017). *Tutor Vista*. Retrieved 17 April 2017.

Kennaway, E. (1955). The Identification of a Carcinogenic Compound in Coal-Tar. *British Medical Journal*, *September* (24), 1955.

MacDonald, D. D., Ingersoll, C. G., & Berger, T. (2000). Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology, 39, 20–31.

Mahler, B. J., Van Metre, P. C., Bashara, T. J., Wilson, J. T., & Johns, D. A. (2005). Parking Lot Sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons. *Environmental Science and Technology*, *39*(15), 5560–5566. https://doi.org/10.1021/es0501565

Mahler, B. J., Van Metre, P. C., Crane, J. L., Watts, A. W., Scoggins, M., & Williams, E. S. (2012). Coal-Tar-Based Pavement Sealcoat and PAHs: Implications for the Environment, Human Health, and Stormwater Management. *Environmental Science and Technology*, *46*, 3039–3045. https://doi.org/10.1021/es203699

Mahler, B. J., Van Metre, P. C., Wilson, J. T., & Musgrove, M. (2010). Coal-Tar-Based Parking Lot Sealcoat: An Unrecognized Source of PAH to Settled House Dust. *Environmental Science and Technology*, *44*(3), 894–900.

Mahler, B. J., Van Metre, P. C., & Foreman, W. T. (2014). Concentrations of polycyclic aromatic hydrocarbons (PAHs) and azaarenes in runoff from coal-tar- and asphalt-sealcoated pavement. Environmental Pollution, 188, 81–87. https://doi.org/10.1016/j.envpol.2014.01.008

McGovern, E. W. (1996). *U.S. Patent No. US5580603 A*. Washington, DC: U.S. Patent and Trademark Office.

Monson, P. D., Call, D. J., Cox, D. A., Liber, K., & Ankley, G. T. (1999). Photoinduced toxicity of fluoranthene to northern leopard frogs. *Environmental Toxicology and Chemistry*, *18*(2), 308–312.

"PDC - Pavement Dressing Conditioner - Asphalt Rejuvenator". Pavement Dressing Conditioner. N.p., 2017. Web. 21 Apr. 2017.

PGDER. 1993. Design Manual for Use of Bioretention in Stormwater Management. Division of Environmental Management, Watershed Protection Branch. Prince George County Department of Environmental Resources, Landover, MD.

Pitch. (1998). *Encyclopedia Britannica*. Retrieved 17 April 2017.

Prabhukumar, G. and Pagilla, K. 2010. *Polycyclic Aromatic Hydrocarbons in Urban Runoff Sources, Sinks and Treatment: A Review*, Chicago, IL: Dep. of Civ., Archit. and Environ. Eng., Inst. of Tech.

Rhea, D. T., Gale, R. W., Orazio, C. E., Peterman, P. H., Harper, D. D., & Farag, A. M. (2005). Polycyclic aromatic hydrocarbons in water, sediment, and snow from lakes in Grand Teton National Park, Wyoming (Final Report, USGS-CERC-91344). Columbia, MO: United States

Geological Survey, Columbia Environmental Research Center.

Sadinski, W. J., Levay, G., Wilson, M. C., Hoffman, J. R., Bodell, W. J., & Anderson, S. L. (1995). Relationships among DNA adducts, micronuclei, and fitness parameters in Xenopus laevis exposed to benzo[a]pyrene. *Aquatic Toxicology*, *32*, 333–352.

Scoggins, M., Mcclintock, N. L., Gosselink, L., Bryer, P., & Gosselink, A. L. (2007). Occurrence of polycyclic aromatic hydrocarbons below coal-tar-sealed parking lots and effects on stream benthic macroinvertebrate communities. *Source Journal of the North American Benthological Society J. N. Am. Benthol. Soc*, *26*(264). https://doi.org/10.1899/06-109.1

Shoenberger, J. E. (2003). "Rejuvenators, rejuvenator/sealers, and seal coats for airfield pavements." ERDC/GSL TR-03-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Singh, R. R., Goyal, N., & Kaur, N. (2015). USE of Coal Tar. *SSRG International Journal of Civil Engineering*, *2*(3), 32–35.

United States Environmental Protection Agency (USEPA). (2011). Assessment of water quality of runoff from sealed asphalt surfaces (Report No. EPA/600/R-10/178). Cincinnati, OH: Office of Research and Development, National Risk Management Research Laboratory-Water Supply and Water Resources Divisions.

US Department of Health and Human Services; Agency for Toxic Substances and Disease Registry. (2002). *Toxicological profile for wood creosote, coal tar, coal tar pitch, and coal tar pitch volatiles*.

Vandenbrouck, T., Jones, O. A. H., Dom, N., Griffin, J. L., & De Coen, W. (2010). Mixtures of similarly acting compounds in Daphnia magna: From gene to metabolite and beyond. *Environment International*, *36*(3), 254–268.

Van Metre, P. C., & Mahler, B. J. (2005). Trends in Hydrophobic Organic Contaminants in Urban and Reference Lake Sediments across the United States, 1970-2001. *Environmental Science and Technology*, *39*(15), 5567–5574. https://doi.org/10.1021/es0503175

Van Metre, P. C., & Mahler, B. J. (2010). Contribution of PAHs from coal–tar pavement sealcoat and other sources to 40 U.S. lakes. *Science of the Total Environment*, *409*, 334–344.

https://doi.org/10.1016/j.scitotenv.2010.08.014

Van Metre, P. C., & Mahler, B. J. (2014). PAH Concentrations in Lake Sediment Decline Following Ban on Coal-Tar-Based Pavement Sealants in Austin, Texas. *Environmental Science and Technology*, *48*, 7222–7228. https://doi.org/10.1021/es405691q

Van Metre, P. C., Mahler, B. J., & Wilson, J. T. (2009). PAHs underfoot: Contaminated dust from coal-tar sealcoated pavement is widespread in the United States. *Environmental Science and Technology*, *43*(1), 20–25. https://doi.org/10.1021/es802119h

Williams, E. S., Mahler, B. J., & Van Metre, P. C. (2012). *Coal-tar pavement sealants might substantially increase children's PAH exposures*. *Environmental Pollution* (Vol. 164). https://doi.org/10.1016/j.envpol.2012.01.010

Williams, E. S., Mahler, B. J., & Van Metre, P. C. (2013). Cancer Risk from Incidental Ingestion Exposures to PAHs Associated with Coal-Tar-Sealed Pavement. *Environmental Science and Technology*, *47*, 1101–1109. https://doi.org/10.1021/es303371t

Appendix A: Gas Chromatogram Instrument Information

Method Information

Method: C:\Chem32\2\METHODS\FID CEC.M
Modified: 4/6/2017 at 8:00:08 PM

Injection Source and Location

Injection Source: Manual

Injection Location: Front

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6890 GC METHOD

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OVEN
Initial temp: 35 'C (On) Maximum temp: 320 'C
Initial time: 4.00 min Equilibration time: 1.00 min
Ramps:

#	Rate	Final temp	Final time
1	3.00	50	0.00
2	8.00	290	3.00
3	0.0(Off)		

Post temp: 50 'C
Post time: 0.00 min
Run time: 42.00 min

FRONT INLET (SPLIT/SPLITLESS)	BACK INLET (SPLIT/SPLITLESS)
Mode: Splitless	Mode: Split
Initial temp: 290 'C (On)	Initial temp: 50 'C (Off)
Pressure: 59.00 psi (On)	Pressure: 11.97 psi (Off)
Purge flow: 100.0 mL/min	Split ratio: 50:1
Purge time: 0.40 min	Split flow: 145.2 mL/min
Total flow: 173.5 mL/min	Total flow: 150.8 mL/min
Gas saver: Off	Gas saver: Off
Gas type: Hydrogen	Gas type: Helium

COLUMN 1	COLUMN 2
Capillary Column	Capillary Column
Nominal length: 30.0 m	Nominal length: 30.0 m
Nominal diameter: 320.00 um	Nominal diameter: 320.00 um
Nominal film thickness: 0.00 um	Nominal film thickness: 0.00 um
Mode: constant pressure	Mode: constant pressure
Pressure: 59.00 psi	Pressure: 11.97 psi
Nominal initial flow: 67.5 mL/min	Nominal initial flow: 2.9 mL/min
Average velocity: 418 cm/sec	Average velocity: 43 cm/sec
Inlet: Front Inlet	Inlet: Back Inlet
Outlet: Front Detector	Outlet: Back Detector
Outlet pressure: ambient	Outlet pressure: ambient

FRONT DETECTOR (FID)	BACK DETECTOR (ECD)
Temperature: 300 'C (On)	Temperature: 250 'C (On)

Hydrogen flow: 40.0 mL/min (On)
Air flow: 400.0 mL/min (On)
Mode: Constant makeup flow
Makeup flow: 45.0 mL/min (On)
Makeup Gas Type: Nitrogen
Flame: On
Electrometer: On
Lit offset: 0.5

Anode purge flow: 6.0 mL/min (On)
Mode: Constant makeup flow
Makeup flow: 60.0 mL/min (On)
Makeup Gas Type: Nitrogen
Adjust offset: 60.00
Electrometer: On

SIGNAL 1
Data rate: 50 Hz
Type: front detector
Save Data: On
Zero: 0.0 (Off)
Range: 0
Fast Peaks: Off
Attenuation: 0

SIGNAL 2
Data rate: 20 Hz
Type: back detector
Save Data: On
Zero: 0.0 (Off)
Range: 0
Fast Peaks: Off
Attenuation: 0

COLUMN COMP 1
Derive from front detector

COLUMN COMP 2
Derive from back detector

POST RUN
Post Time: 0.00 min

TIME TABLE

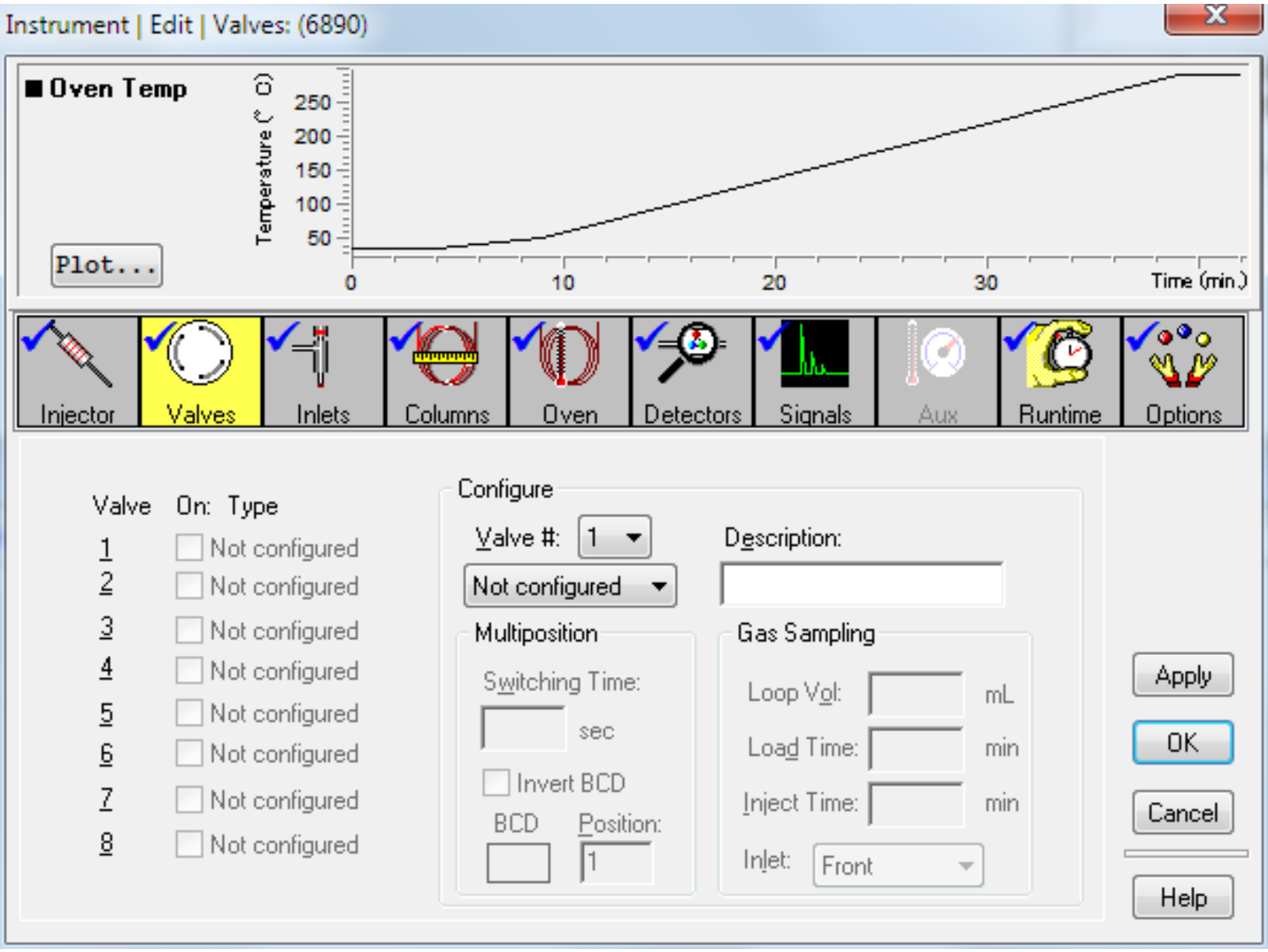
Time	Specifier	Parameter & Setpoint

GC Injector

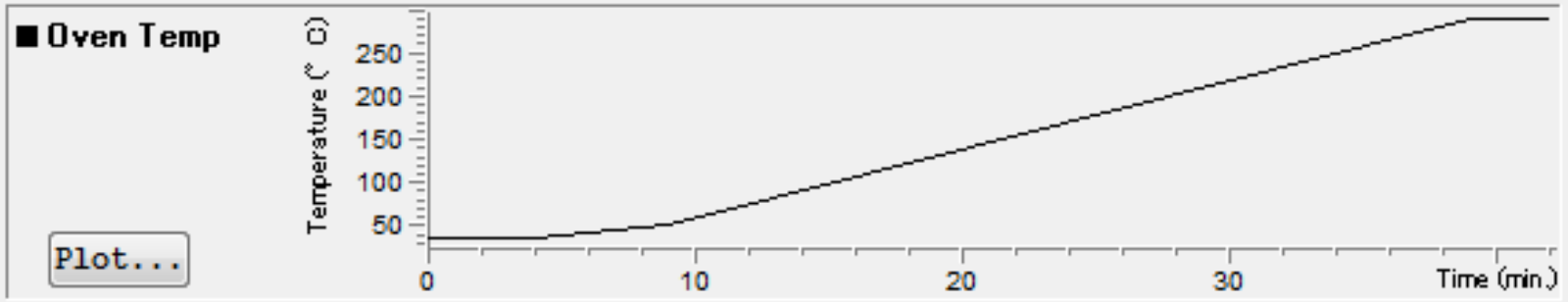
Front Injector:

Sample Washes	0
Sample Pumps	0
Injection Volume	2.00 microliters
Syringe Size	10.0 microliters
PreInj Solvent A Washes	0
PreInj Solvent B Washes	0
PostInj Solvent A Washes	0
PostInj Solvent B Washes	0
Viscosity Delay	0 seconds
Plunger Speed	Fast
PreInjection Dwell	0.00 minutes
PostInjection Dwell	0.00 minutes

Back Injector:
No parameters specified


Instrument | Edit | Valves: (6890)
Oven Temp
Temperature (° C)
250
200
150
100
50
0
10
20
30
Time (min)
Plot...
Injector
Valves
Inlets
Columns
Oven
Detectors
Signals
Aux
Runtime
Options
Valve
On:
Type
1 Not configured
2 Not configured
3 Not configured
4 Not configured
5 Not configured
6 Not configured
7 Not configured
8 Not configured
Configure
Valve #: 1
Not configured
Description:
Multiposition
Switching Time:
sec
Invert BCD
BCD
Position: 1
Gas Sampling
Loop Vol:
mL
Load Time:
min
Inject Time:
min
Inlet: Front
Apply
OK
Cancel
Help

Instrument | Edit | Inlets: (6890)



Injector | Valves | Inlets | Columns | Oven | Detectors | Signals | Aux | Runtime | Options

Front: EPC Split-Splitless Inlet

Mode: Splitless Gas: H2

On	Actual	Setpoint
Heater, °C	290	290
Pressure, psi	58.99	59.00
Total Flow, mL/min	131	173

Purge Flow to Split Vent: 100 mL/min @ 0.40 min

GasSaver: 20.0 mL/min @ 2.00 min

Front

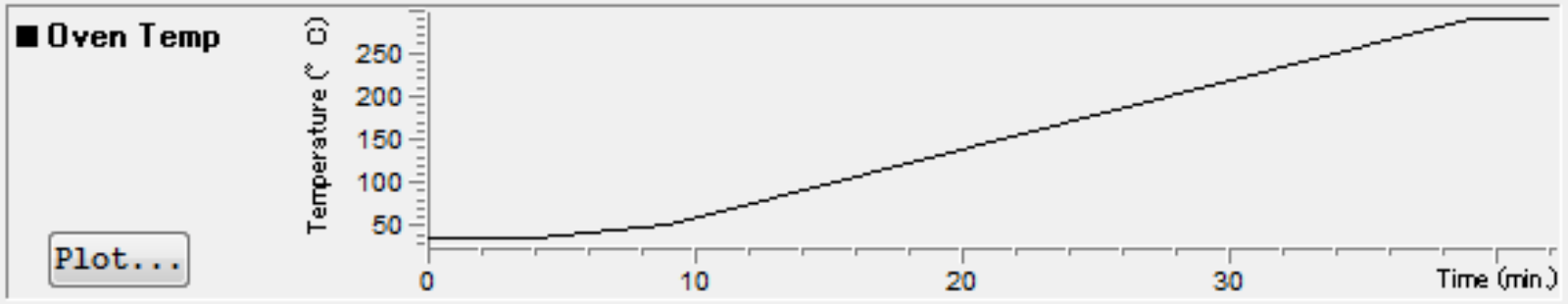
Apply

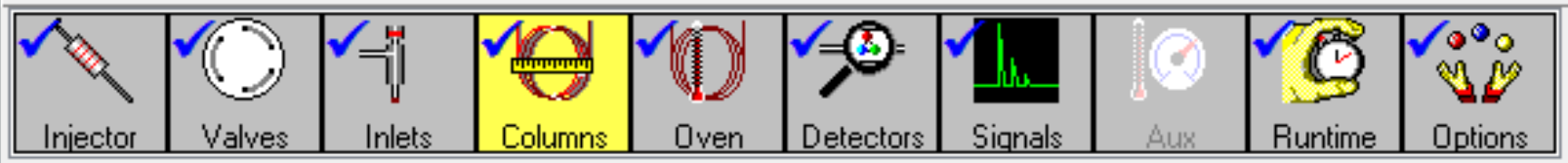
OK

Cancel

Help

Instrument | Edit | Columns: (6890)





Column
1
2

Mode: Const Pressure

Inlet: Front

Detector: Front

Outlet psi: Ambient

Installed Column
Inventory# AB001
30.0 m × 250 µm × 0.00 µm calibrated

Column Dimensions
Capillary 30.0 m × 320 µm × 0.00 µm

Change...

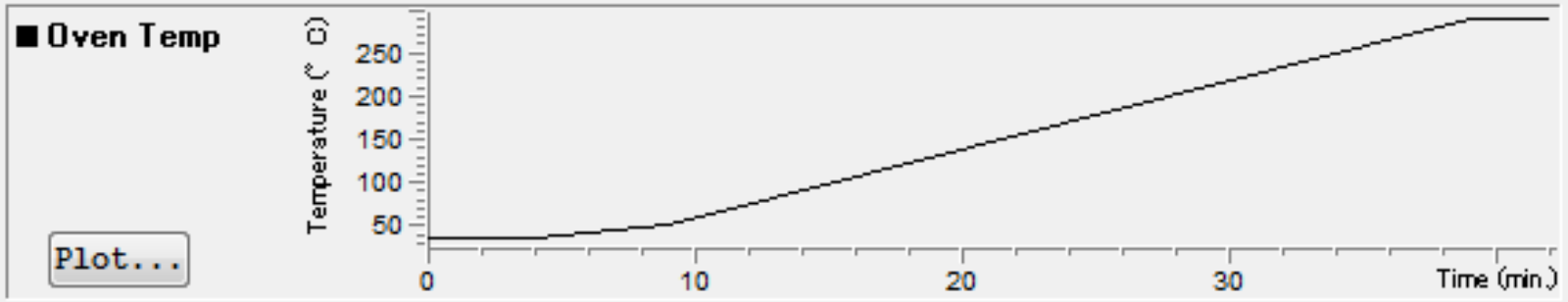
H2 Flow

	Setpoint	Actual	
Pressure:	59.00	58.99	psi
Flow:	25.1	25.1	ml/min
Average Velocity:	255		cm/sec

Pressure	psi/min	Next psi	Hold min	Run Time
Initial		59.00	0.00	42.00
Ramp 1	0.00	0.00	0.00	
Ramp 2	0.00	0.00	0.00	
Ramp 3	0.00	0.00	0.00	
Post Run			0.00	42.00

Apply
OK
Cancel
Help

Instrument | Edit | Oven: (6890)



Injector | Valves | Inlets | Columns | Oven | Detectors | Signals | Aux | Runtime | Options

Oven

On

Setpoint °C: 35

Actual °C: 35

Oven Configuration

Maximum °C: 320

Equilibration min: 1.00

Oven Ramp	°C/min	Next °C	Hold min	Run Time
Initial		35	4.00	4.00
Ramp 1	3.00	50	0.00	9.00
Ramp 2	8.00	290	3.00	42.00
Ramp 3	0.00	0	0.00	
Ramp 4	0.00	0	0.00	
Ramp 5	0.00	0	0.00	
Ramp 6	0.00	0	0.00	
Post Run		50	0.00	42.00

Cryo Configuration

Cryo On

Quick Cooling On

°C, Ambient

Timeout Detection On

min

Fault Detection On

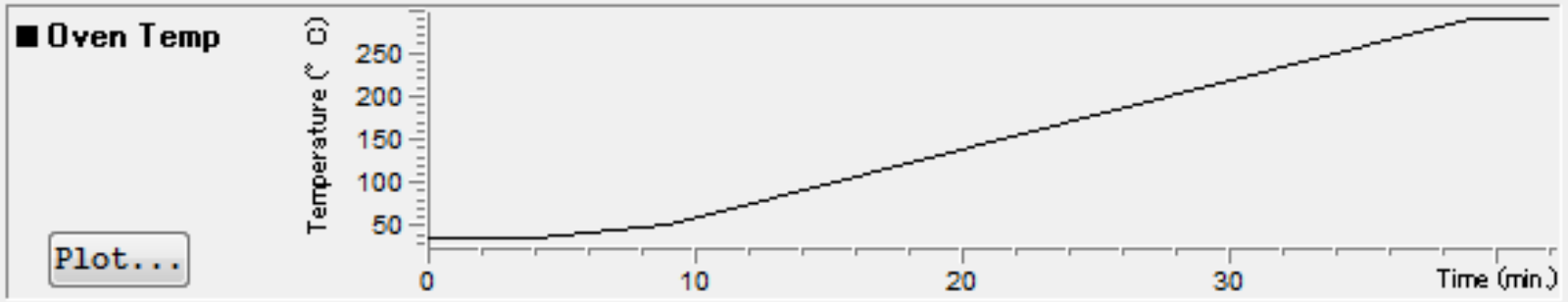
Apply

OK

Cancel

Help

Instrument | Edit | Detectors: (6890)



Injector | Valves | Inlets | Columns | Oven | Detectors | Signals | Aux | Runtime | Options

Front: FID Detector

On	Actual	Setpoint
Heater, °C	300	300
H2 Flow, mL/min	40.0	40.0
Air Flow, mL/min	400	400
Makeup Flow: N2	45.0	45.0
Const Col + Makeup, mL/min:		45.0
Flame	On	
Electrometer	Reignite	

	Setpoint
Lit Offset:	0.5

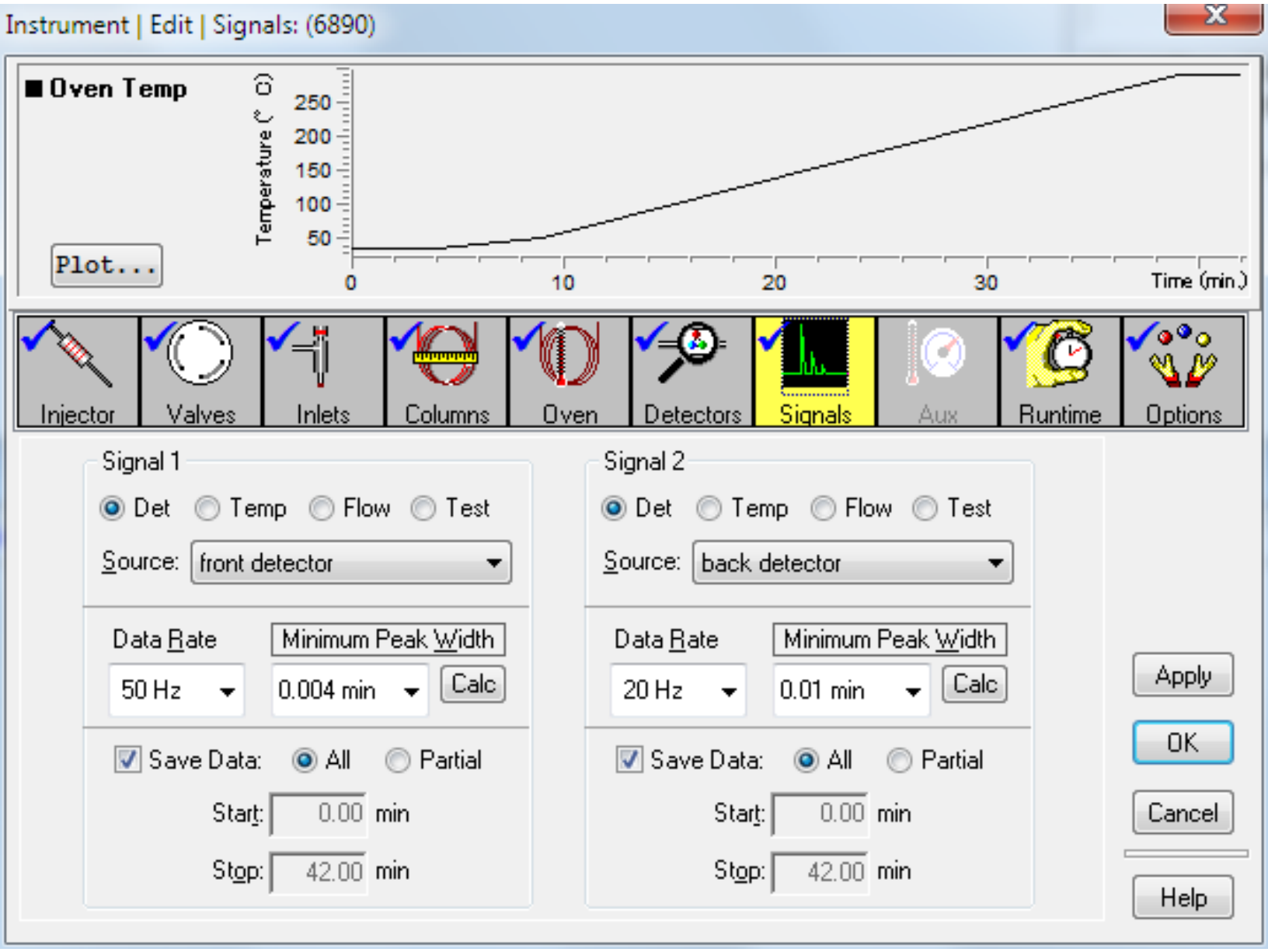
Front

Apply

OK

Cancel

Help

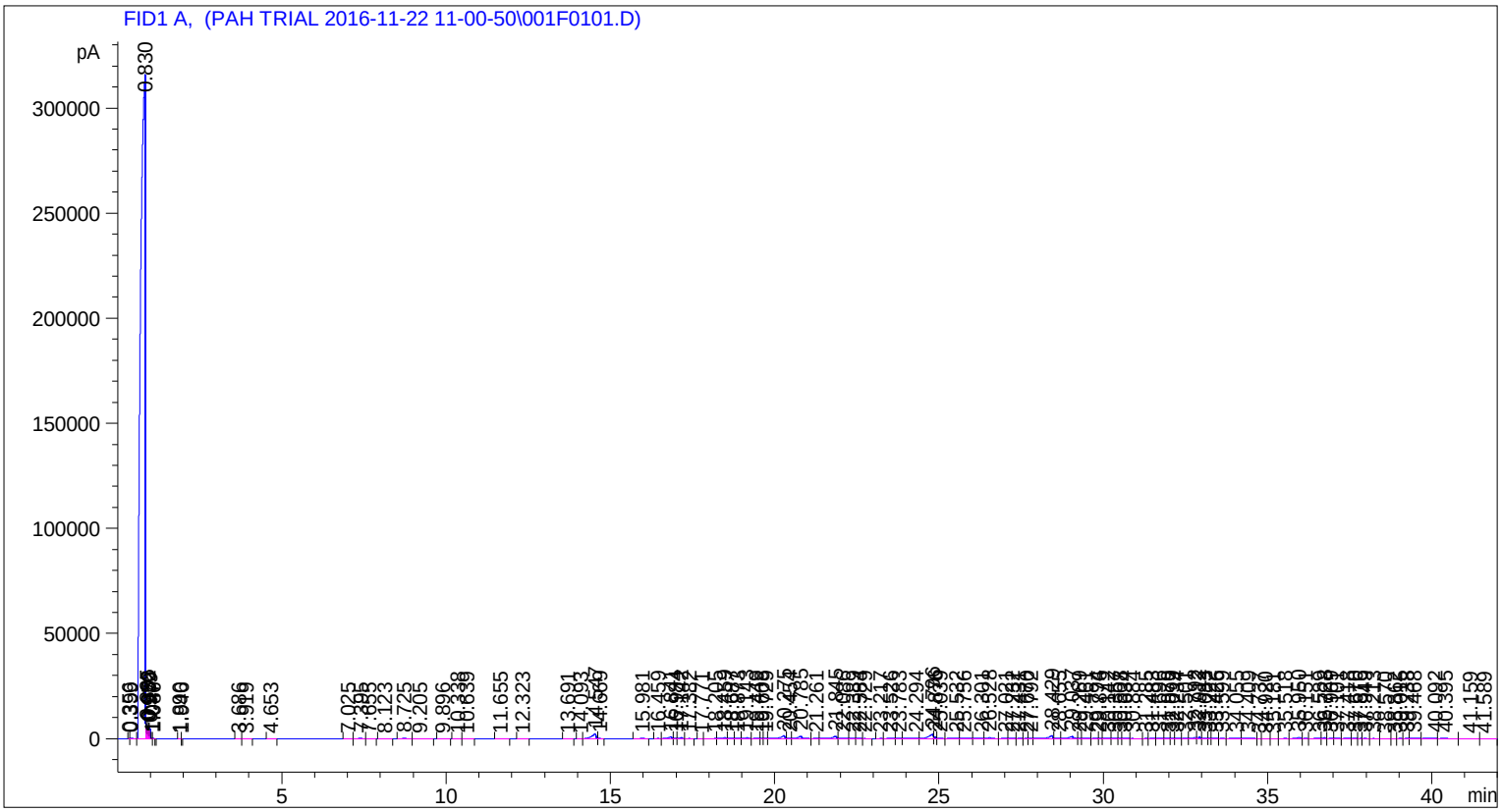

Instrument | Edit | Signals: (6890)
Oven Temp
Temperature (° C)
250
200
150
100
50
0
10
20
30
Time (min)
Plot...
Injector
Valves
Inlets
Columns
Oven
Detectors
Signals
Aux
Runtime
Options
Signal 1
Det
Temp
Flow
Test
Source:
front detector
Data Rate
Minimum Peak Width
50 Hz
0.004 min
Calc
Save Data:
All
Partial
Start:
0.00
min
Stop:
42.00
min
Signal 2
Det
Temp
Flow
Test
Source:
back detector
Data Rate
Minimum Peak Width
20 Hz
0.01 min
Calc
Save Data:
All
Partial
Start:
0.00
min
Stop:
42.00
min
Apply
OK
Cancel
Help

Appendix B: Sample Chromatograph

Data File C:\CHEM32\2\DATA\PAH TRIAL 2016-11-22 11-00-50\001F0101.D
Sample Name: CT 1%

```
=====================================================================
Acq. Operator   :                                Seq. Line :   1
Acq. Instrument : Instrument 2                    Location : Vial 1
Injection Date  : 11/22/2016 11:08:36 AM               Inj :   1
                                                 Inj Volume : 2 µl
Acq. Method     : C:\CHEM32\2\DATA\PAH TRIAL 2016-11-22 11-00-50\FID CEC.M
Last changed    : 8/18/2016 8:56:01 AM
Analysis Method : C:\CHEM32\2\METHODS\FID CEC.M
Last changed    : 8/18/2016 8:56:01 AM
Method Info     : Method to demo HP 6890 parameter editing for Split/Splitless & Purged
                  Packed inlets plus FID and TCD.  This method is for the purpose of OFFLINE
                  demos only!

                  In order to load this method use the macro "6890demo.mac" or copy the file
                  'IQ1.MTH' from this methods' subdirectory to the instrument subdirectory
                  and rename it 'IQ1.cfg'.  The method can then be loaded
                  and will show appropriate parameters.
```




```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs
```

Signal 1: FID1 A,

Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	0.356	BV	0.0298	247.64001	115.37025	0.00740
2	0.399	VB	0.0535	452.45557	103.34491	0.01353
3	0.830	BV S	0.1208	3.09650e6	3.15835e5	92.57197
4	0.895	VV S	0.0352	1.32556e4	6279.35400	0.39628
5	0.932	VV S	0.0300	1.04114e4	5779.47021	0.31126
6	0.956	VV S	0.0163	5066.24023	5176.57178	0.15146
7	0.979	VB S	0.0338	9694.92578	4780.36523	0.28984
8	1.047	BV X	0.0178	99.87376	89.93181	0.00299
9	1.086	VB X	0.0170	75.06015	67.40880	0.00224
10	1.890	BV	0.0407	48.63874	18.75255	0.00145
11	1.946	VB	0.0224	5.48649	3.33301	0.00016
12	3.686	BV	0.0930	54.22813	9.28193	0.00162
13	3.919	VB	0.1034	191.73958	29.03655	0.00573
14	4.653	BB	0.1143	84.64105	11.65762	0.00253
15	7.025	BV	0.1408	139.95628	15.00474	0.00418
16	7.395	VV	0.1629	786.80048	73.70528	0.02352
17	7.655	VB	0.1458	252.20129	25.85275	0.00754
18	8.123	BB	0.1537	175.50198	17.75133	0.00525
19	8.725	BV	0.1575	809.56964	76.24789	0.02420
20	9.205	VB	0.1700	355.48282	30.41361	0.01063
21	9.896	BB	0.1568	148.07698	13.84348	0.00443
22	10.338	BV	0.1335	350.39615	39.05690	0.01048
23	10.639	VB	0.1328	283.64108	32.83161	0.00848
24	11.655	BB	0.1351	112.03503	11.93902	0.00335
25	12.323	BB	0.1345	267.63113	29.99870	0.00800
26	13.691	BB	0.1251	63.90857	7.73985	0.00191
27	14.093	BV	0.0972	106.83630	16.65815	0.00319
28	14.547	VV	0.1225	2.04259e4	2204.84985	0.61065
29	14.669	VB	0.0748	545.71924	114.50021	0.01631
30	15.981	BB	0.1114	1125.89905	147.62181	0.03366
31	16.459	BV	0.1032	424.16873	60.04544	0.01268
32	16.841	VV	0.1183	6593.75195	775.99249	0.19712
33	16.984	VV	0.0787	1146.63513	213.31862	0.03428
34	17.142	VV	0.0951	3024.44409	474.86130	0.09042
35	17.382	VB	0.1029	383.27402	55.53060	0.01146
36	17.771	BV	0.0905	56.40601	9.23373	0.00169
37	18.205	VV	0.1256	695.12488	75.07777	0.02078
38	18.459	VV	0.1212	3585.45264	423.38022	0.10719
39	18.687	VV	0.1224	1687.96289	200.03625	0.05046
40	18.873	VV	0.1128	2357.00146	304.16129	0.07046
41	19.143	VV	0.1339	3160.58130	361.89606	0.09449
42	19.449	VV	0.1415	1201.23340	128.00771	0.03591
43	19.608	VV	0.0671	204.13757	43.87591	0.00610
44	19.729	VV	0.0930	455.35190	68.97829	0.01361
45	20.275	VV	0.1287	1.39233e4	1462.57385	0.41625
46	20.454	VV	0.1166	1405.88757	177.17386	0.04203
47	20.785	VV	0.1268	1.05465e4	1160.30249	0.31529
48	21.261	VV	0.1476	703.48651	71.01243	0.02103
49	21.845	VV	0.1239	1.07974e4	1202.86853	0.32280
50	22.086	VV	0.1498	2507.52856	218.70723	0.07496
51	22.389	VV	0.1001	1280.11011	188.23062	0.03827

Data File C:\CHEM32\2\DATA\PAH TRIAL 2016-11-22 11-00-50\001F0101.D
Sample Name: CT 1%

Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
52	22.584	VV	0.0879	1335.85193	226.76123	0.03994
53	22.729	VB	0.1151	232.00146	27.75985	0.00694
54	23.217	BV	0.0921	269.82956	44.13832	0.00807
55	23.526	VV	0.1459	1232.60791	116.48355	0.03685
56	23.783	VV	0.1290	742.58978	81.24333	0.02220
57	24.294	VV	0.2005	4447.57617	296.67477	0.13296
58	24.796	VV	0.1344	2.11158e4	2110.00806	0.63127
59	24.876	VV	0.0444	2308.80225	774.99298	0.06902
60	25.039	VV	0.1147	706.06281	89.22630	0.02111
61	25.532	VV	0.1257	2502.84644	278.45749	0.07482
62	25.756	VV	0.2298	1267.96741	72.45081	0.03791
63	26.301	VV	0.1452	2729.44019	249.54494	0.08160
64	26.528	VV	0.1317	3779.17285	391.86627	0.11298
65	27.021	VV	0.1583	601.62915	51.05106	0.01799
66	27.232	VV	0.1048	1054.73206	146.40396	0.03153
67	27.431	VV	0.1378	385.68698	38.97593	0.01153
68	27.670	VV	0.1054	330.76987	44.78569	0.00989
69	27.792	VV	0.1178	488.31259	57.76149	0.01460
70	28.429	VV	0.1223	1.29047e4	1375.26428	0.38579
71	28.655	VV	0.1156	600.91864	73.97042	0.01796
72	29.037	VV	0.1295	1.06800e4	1067.33875	0.31929
73	29.269	VV	0.0729	380.17944	77.93209	0.01137
74	29.461	VV	0.1382	1155.94226	118.12100	0.03456
75	29.794	VV	0.1109	793.67163	92.91200	0.02373
76	29.876	VV	0.0778	413.70340	78.14604	0.01237
77	30.142	VV	0.1083	2118.90356	282.60214	0.06335
78	30.357	VV	0.1121	2375.99023	320.54367	0.07103
79	30.508	VV	0.0845	605.75604	105.68799	0.01811
80	30.634	VV	0.1229	1055.30652	118.73388	0.03155
81	30.884	VB	0.2081	434.49716	26.17453	0.01299
82	31.285	BV	0.0974	353.64395	52.75666	0.01057
83	31.483	VV	0.1102	605.57928	79.03891	0.01810
84	31.696	VV	0.1508	755.28027	75.20078	0.02258
85	31.979	VV	0.1043	847.98248	118.46111	0.02535
86	32.099	VV	0.0847	820.72345	146.27789	0.02454
87	32.234	VV	0.1128	674.22864	86.99130	0.02016
88	32.501	VV	0.1360	522.32751	53.64258	0.01562
89	32.792	VV	0.1206	4064.99658	491.18686	0.12153
90	32.912	VV	0.0728	3406.94946	681.14722	0.10185
91	33.083	VV	0.0839	1001.56299	176.33800	0.02994
92	33.222	VV	0.0762	209.84227	38.61619	0.00627
93	33.426	VV	0.1440	755.04541	79.76187	0.02257
94	33.599	VV	0.1014	565.71997	83.52370	0.01691
95	34.055	VV	0.1974	1438.32166	95.88203	0.04300
96	34.409	VV	0.1778	1539.50330	116.74401	0.04602
97	34.737	VV	0.0828	132.59192	24.30949	0.00396
98	34.920	VV	0.1746	192.34831	15.91021	0.00575
99	35.181	VV	0.1425	247.04623	21.68373	0.00739
100	35.518	VV	0.1727	418.42834	29.92410	0.01251
101	35.950	VV	0.1309	4308.86670	477.31006	0.12882
102	36.151	VV	0.0842	497.84534	91.59615	0.01488
103	36.589	VV	0.1345	1699.35242	182.01097	0.05080
104	36.728	VV	0.0831	2161.41797	394.90735	0.06462
105	36.909	VV	0.0889	670.39661	109.71268	0.02004

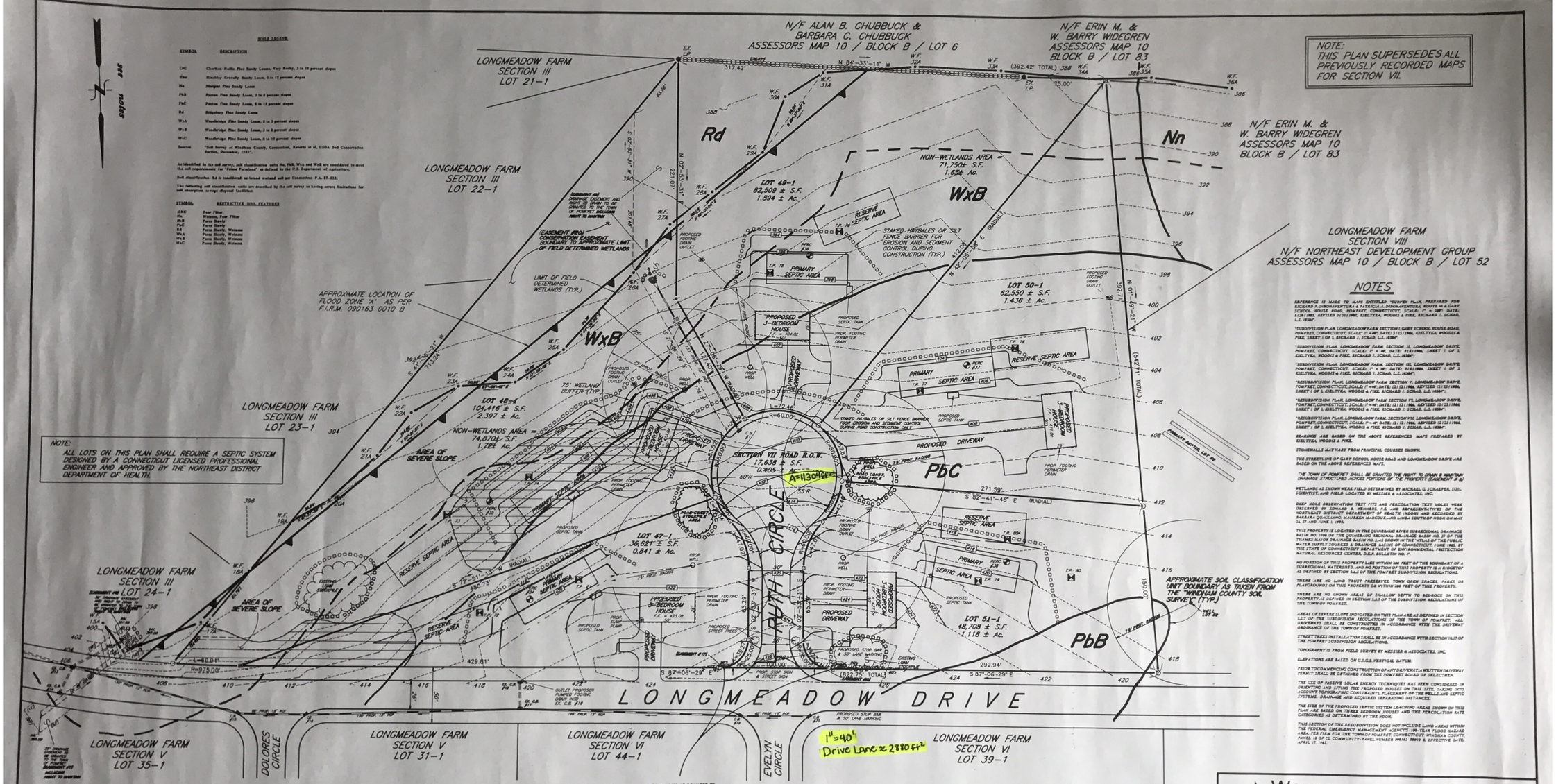
Data File C:\CHEM32\2\DATA\PAH TRIAL 2016-11-22 11-00-50\001F0101.D
Sample Name: CT 1%

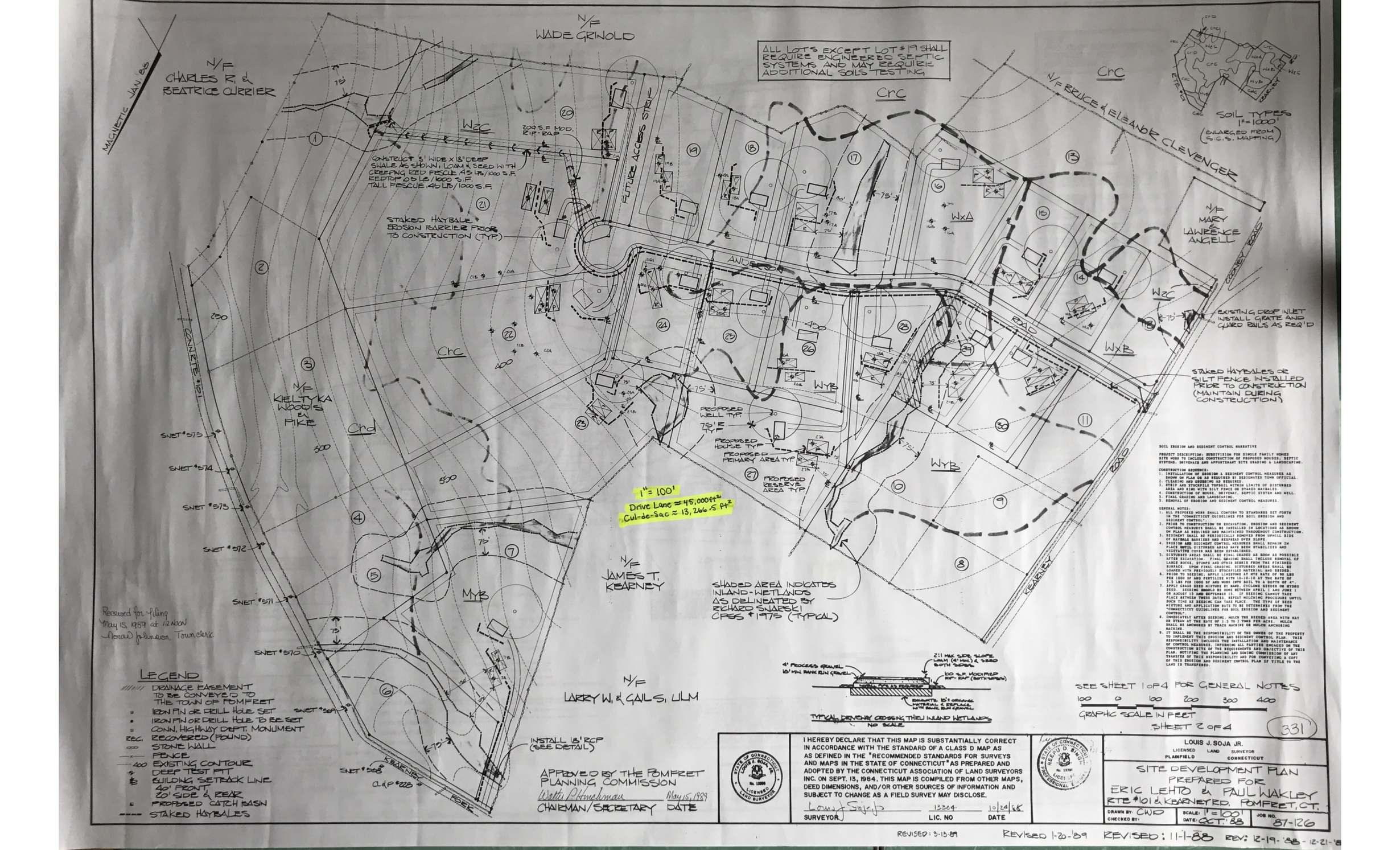
Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
106	37.101	VV	0.1311	453.10971	42.94899	0.01355
107	37.418	VV	0.1601	826.42493	71.67190	0.02471
108	37.670	VV	0.1328	396.41891	40.71420	0.01185
109	37.816	VV	0.0942	192.87010	29.39378	0.00577
110	37.949	VV	0.1155	315.41541	39.53101	0.00943
111	38.213	VV	0.1392	261.91501	27.28049	0.00783
112	38.570	VV	0.1852	316.39777	21.21478	0.00946
113	38.862	VV	0.1074	181.59547	24.01699	0.00543
114	39.015	VV	0.1296	306.16156	29.75664	0.00915
115	39.238	VV	0.1199	369.90384	44.24081	0.01106
116	39.468	VV	0.1696	2394.79688	194.07883	0.07159
117	40.092	VV	0.1576	2302.73608	194.08315	0.06884
118	40.395	VV	0.1649	920.28027	74.51212	0.02751
119	41.159	VV	0.3256	363.58829	13.49099	0.01087
120	41.589	VBA	0.2072	144.85022	9.22639	0.00433
Totals :				3.34497e6	3.62247e5	

==========

*** End of Report ***

Appendix C: Site Surface Area Calculations


N/F ALAN B. CHUBBUCK & BARBARA C. CHUBBUCK ASSESSORS MAP 10 / BLOCK B / LOT 6
N/F ERIN M. & W. BARRY WIDEGREN ASSESSORS MAP 10 BLOCK B / LOT 83
N/F ERIN M. & W. BARRY WIDEGREN ASSESSORS MAP 10 BLOCK B / LOT 83
LONGMEADOW FARM SECTION III LOT 21-1
LONGMEADOW FARM SECTION III LOT 22-1
LONGMEADOW FARM SECTION III LOT 23-1
LONGMEADOW FARM SECTION III LOT 24-1
LONGMEADOW FARM SECTION V LOT 35-1
LONGMEADOW FARM SECTION V LOT 31-1
LONGMEADOW FARM SECTION VI LOT 44-1
LONGMEADOW FARM SECTION VI LOT 39-1
LONGMEADOW FARM SECTION VIII N/F NORTHEAST DEVELOPMENT GROUP ASSESSORS MAP 10 / BLOCK B / LOT 52
LONGMEADOW DRIVE
RUTH CIRCLE
DOLORES CIRCLE
EVELYN CIRCLE
LOT 49-1 82,509 ± S.F. 1.894 ± Ac.
LOT 50-1 62,550 ± S.F. 1.436 ± Ac.
LOT 48-1 104,416 ± S.F. 2.397 ± Ac.
LOT 47-1 36,821 ± S.F. 0.841 ± Ac.
LOT 51-1 48,708 ± S.F. 1.118 ± Ac.
SECTION VII ROAD R.O.W. 17,638 ± S.F. 0.405 ± Ac.
NON-WETLANDS AREA = 71,758± S.F. 1.655± Ac.
NON-WETLANDS AREA = 74,870± S.F. 1.72± Ac.
PROPOSED 3-BEDROOM HOUSE
PROPOSED DRIVEWAY
PRIMARY SEPTIC AREA
RESERVE SEPTIC AREA
PROPOSED SEPTIC TANK
PROPOSED FOOTING DRAIN OUTLET
PROP. FOOTING PERIMETER DRAIN
PROP. WELL
STAKED HAYBALES OR SILT FENCE BARRIER FOR EROSION AND SEDIMENT CONTROL DURING CONSTRUCTION (TYP.)
LIMIT OF FIELD DETERMINED WETLANDS (TYP.)
75' WETLAND BUFFER (TYP.)
APPROXIMATE LOCATION OF FLOOD ZONE 'A' AS PER F.I.R.M. 090163 0010 B
AREA OF SEVERE SLOPE
EXISTING LOW STONEWALL
PROPOSED STREET TREES
PROPOSED STOP BAR & 30' LANE MARKING
EXISTING STOP SIGN & STREET SIGN
EASEMENT #1 (TYP.)
EASEMENT #2
EASEMENT #3
EASEMENT #4
EASEMENT #5
EASEMENT #6
EASEMENT #7
EASEMENT #8
EASEMENT #9
EASEMENT #10
EASEMENT #11
EASEMENT #12
EASEMENT #13
EASEMENT #14
EASEMENT #15
EASEMENT #16
EASEMENT #17
EASEMENT #18
EASEMENT #19
EASEMENT #20
EASEMENT #21
EASEMENT



SOIL EROSION AND SEDIMENT CONTROL NARRATIVE

PROJECT DESCRIPTION: SUBDIVISION FOR SINGLE FAMILY HOMES SITE WORK TO INCLUDE CONSTRUCTION OF PROPOSED HOUSES, SEPTIC SYSTEMS, DRIVEWAYS AND APPURTENANT SITE GRADING & LANDSCAPING.

CONSTRUCTION SEQUENCE:
1. INSTALLATION OF EROSION & SEDIMENT CONTROL MEASURES AS SHOWN ON PLAN OR AS REQUIRED BY DESIGNATED TOWN OFFICIAL.
2. CLEARING AND GRUBBING AS REQUIRED.
3. STRIP AND STOCKPILE TOPSOIL WITHIN LIMITS OF DISTURBED AREA AND RING WITH SILT FENCE OR STAKED HAYBALES.
4. CONSTRUCTION OF HOUSE, DRIVEWAY, SEPTIC SYSTEM AND WELL.
5. FINAL GRADING AND LANDSCAPING.
6. REMOVAL OF EROSION AND SEDIMENT CONTROL MEASURES.

GENERAL NOTES:
1. ALL PROPOSED WORK SHALL CONFORM TO STANDARDS SET FORTH IN THE "CONNECTICUT GUIDELINES FOR SOIL EROSION AND SEDIMENT CONTROL".
2. PRIOR TO CONSTRUCTION OR EXCAVATION, EROSION AND SEDIMENT CONTROL MEASURES SHALL BE INSTALLED IN LOCATIONS AS SHOWN ON PLAN AS REQUIRED AND MAINTAINED THROUGHOUT CONSTRUCTION.
3. SEDIMENT SHALL BE PERIODICALLY REMOVED FROM UPHILL SIDE OF HAYBALE BARRIERS AND RESPREAD OVER SLOPE.
4. EROSION AND SEDIMENT CONTROL MEASURES SHALL REMAIN IN PLACE UNTIL DISTURBED AREAS HAVE BEEN STABILIZED AND VEGETATIVE COVER HAS BEEN ESTABLISHED.
5. DISTURBED AREAS SHALL BE FINAL GRADED AS SOON AS POSSIBLE AFTER EXCAVATION. FINAL GRADING SHALL INCLUDE REMOVAL OF LARGE ROCKS, STUMPS AND OTHER DEBRIS FROM THE FINISHED SURFACE. UPON FINAL GRADING, DISTURBED AREAS SHALL BE LOAMED WITH PREVIOUSLY STOCKPILED MATERIAL AND SEEDED.
6. PRIOR TO SEEDING, APPLY LIMESTONE AT 4YR RATE OF 90 LBS PER 1000 SF AND FERTILIZE WITH 10-10-10 AT THE RATE OF 7 LBS PER 1000 SF AND WORK INTO SOIL TO A DEPTH OF 4".
7. APPLY GRASS SEED MIXTURES #1 OR #2 AS FOLLOWS BY HYDRO SEED: #1 FROM APRIL 1 TO MAY 15 AND AUGUST 15 TO OCTOBER 15 OR AUGUST 15 AND SEPTEMBER 15. IF SEEDING CANNOT TAKE PLACE BETWEEN THESE DATES, APPLY MULCHING PROCEDURES UNTIL SUCH TIME AS SEEDING CAN TAKE PLACE. THE TYPE OF SEED MIXTURE AND APPLICATION RATE TO BE DETERMINED FROM THE "CONNECTICUT GUIDELINES FOR SOIL EROSION AND SEDIMENT CONTROL".
8. IMMEDIATELY AFTER SEEDING, MULCH THE SEEDED AREA WITH HAY OR STRAW AT THE RATE OF 1.5 TO 2 TONS PER ACRE. MULCH SHALL BE ANCHORED BY TRACK MACHINE OR MULCH ANCHORING MACHINE.
9. IT SHALL BE THE RESPONSIBILITY OF THE OWNER OF THE PROPERTY TO IMPLEMENT THIS EROSION AND SEDIMENT CONTROL PLAN. THIS RESPONSIBILITY INCLUDES THE INSTALLATION AND MAINTENANCE OF CONTROL MEASURES, INFORMING ALL PARTIES ENGAGED ON THE CONSTRUCTION SITE OF THE REQUIREMENTS AND OBJECTIVE OF THIS PLAN, NOTIFYING THE PLANNING AND ZONING COMMISSION OF ANY TRANSFER OF THIS RESPONSIBILITY AND FOR CONVEYING A COPY OF THIS EROSION AND SEDIMENT CONTROL PLAN IF TITLE TO THE LAND IS TRANSFERED.

LEGEND
- DRAINAGE EASEMENT TO BE CONVEYED TO THE TOWN OF POMFRET
- IRON PIN OR DRILL HOLE SET
- IRON PIN OR DRILL HOLE TO BE SET
- CONN. HIGHWAY DEPT. MONUMENT
- REC. RECOVERED (FOUND)
- STONE WALL
- FENCE
- 400 EXISTING CONTOUR
- DEEP TEST PIT
- BUILDING SETBACK LINE 40' FRONT 20' SIDE & REAR
- PROPOSED CATCH BASIN
- STAKED HAYBALES

Received for filing May 15, 1989 at 12 NOON
Norma Johnson, Town Clerk

APPROVED BY THE POMFRET PLANNING COMMISSION
Walter P. Hinchman — May 15, 1989
CHAIRMAN/SECRETARY — DATE

I HEREBY DECLARE THAT THIS MAP IS SUBSTANTIALLY CORRECT IN ACCORDANCE WITH THE STANDARD OF A CLASS D MAP AS AS DEFINED IN THE "RECOMMENDED STANDARDS FOR SURVEYS AND MAPS IN THE STATE OF CONNECTICUT" AS PREPARED AND ADOPTED BY THE CONNECTICUT ASSOCIATION OF LAND SURVEYORS INC. ON SEPT. 13, 1984. THIS MAP IS COMPILED FROM OTHER MAPS, DEED DIMENSIONS, AND/OR OTHER SOURCES OF INFORMATION AND SUBJECT TO CHANGE AS A FIELD SURVEY MAY DISCLOSE.

Louis J. Soja Jr. — 13304 — 10/24/88
SURVEYOR — LIC. NO — DATE

LOUIS J. SOJA JR.
LICENSED LAND SURVEYOR
PLAINFIELD CONNECTICUT

SITE DEVELOPMENT PLAN PREPARED FOR ERIC LEHTO & PAUL WAKLEY

RTE #101 & KEARNEY RD. POMFRET, CT.

DRAWN BY: CWD
CHECKED BY:
SCALE: 1" = 100'
DATE: OCT. '88
JOB NO. 87-126

REVISED: 3-13-89 REVISED 1-20-'89 REVISED: 11-1-88 REV: 12-19-'88 - 12-21-'8

Appendix D: Additional Site Photos


Great Value
STRONG BRISTLES
Easy Sweeping Rubber Edged Pan
Dust Broom & Dustpan
DISTRIBUTED BY:
Wal-Mart Stores, Inc.,
Bentonville, AR 72716
PRODUCT OF CHINA
CS-2